This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

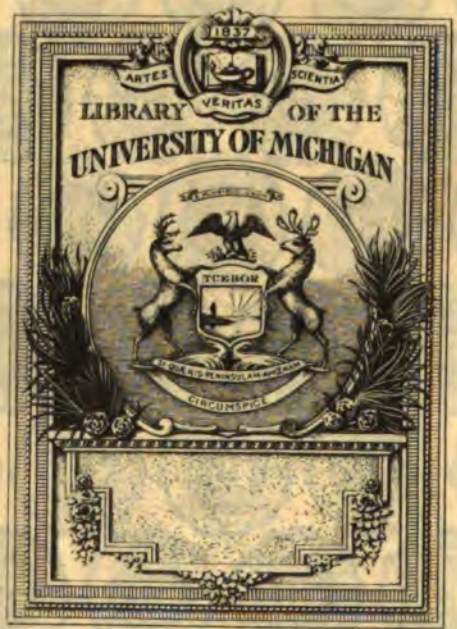
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 430473

Digitized by Google



Digitized by Google

Digitized by Google

Digitized by Google

TN
24
.T2
A4

Digitized by Google

Digitized by Google

APR 24 1917
UNIV. OF MICH.
LIBRARY

TN
24
T2
A4

STATE OF TENNESSEE

STATE GEOLOGICAL SURVEY

A. H. PURDUE, STATE GEOLOGIST

Tennessee. Geological survey.

THE RESOURCES OF TENNESSEE

VOLUMES V AND VI

NASHVILLE
1916

Digitized by Google

Digitized by Google

GENERAL LIBRARY
JAN21 1915
TN
24
.T2
A4

Volume V Number 1

JANUARY, 1915

Tennessee. Geol. survey

THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY, AND OCTOBER
BY THE STATE GEOLOGICAL
SURVEY
NASHVILLE, TENNESSEE

A Magazine Devoted to the Description, Conservation, and Development of the Resources of Tennessee

CONTENTS

The Hydro-Electric System of Tennessee.....J. A. Switzer
West Tennessee Gullied Lands and their Reclamation.....R. S. Maddox
The White Phosphates of Tennessee.....J. S. Hook
Publications of the Geological Survey of Tennessee.

Entered as second-class matter January 10, 19 13, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

Volume V **Number 1**

JANUARY, 1915

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey

NASHVILLE, TENNESSEE

STATE GEOLOGICAL COMMISSION

Gov. BEN W. HOOPER, *Chairman*

DR. BROWN AYERS, *Secretary*
President, University of Tennessee

CAPT. T. F. PECK
Commissioner of Agriculture

DR. J. H. KIRKLAND
Chancellor, Vanderbilt University

DR. A. W. KNIGHT
Vice-Chancellor, University of the South

GEO. E. SYLVESTER
Chief Mine Inspector

GEOLOGICAL CORPS

A. H. PURDUE
State Geologist

OLAF P. JENKINS
Assistant Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

CONTENTS

The Hydro-Electric System of Tennessee.....J. A. Switzer
West Tennessee Gullied Lands and their Reclamation.....R. S. Maddox
The White Phosphates of Tennessee.....J. S. Hook
Publications of the Geological Survey of Tennessee.

Digitized by Google

TN
24
.T2
A4

Corrections

In Vol. IV, No. 4, make the following corrections:

Page 161. Line 11, For "Laurel earthy limestone member," read "Laurel limestone member".

Page 161. Following line 11, and coördinate with "Laurel limestone member", insert "Osgood earthy limestone member".

Page 167. Line 3. For "Mary" read "Maury".

Page 167. Line 8. For "Sreek" read "Creek".

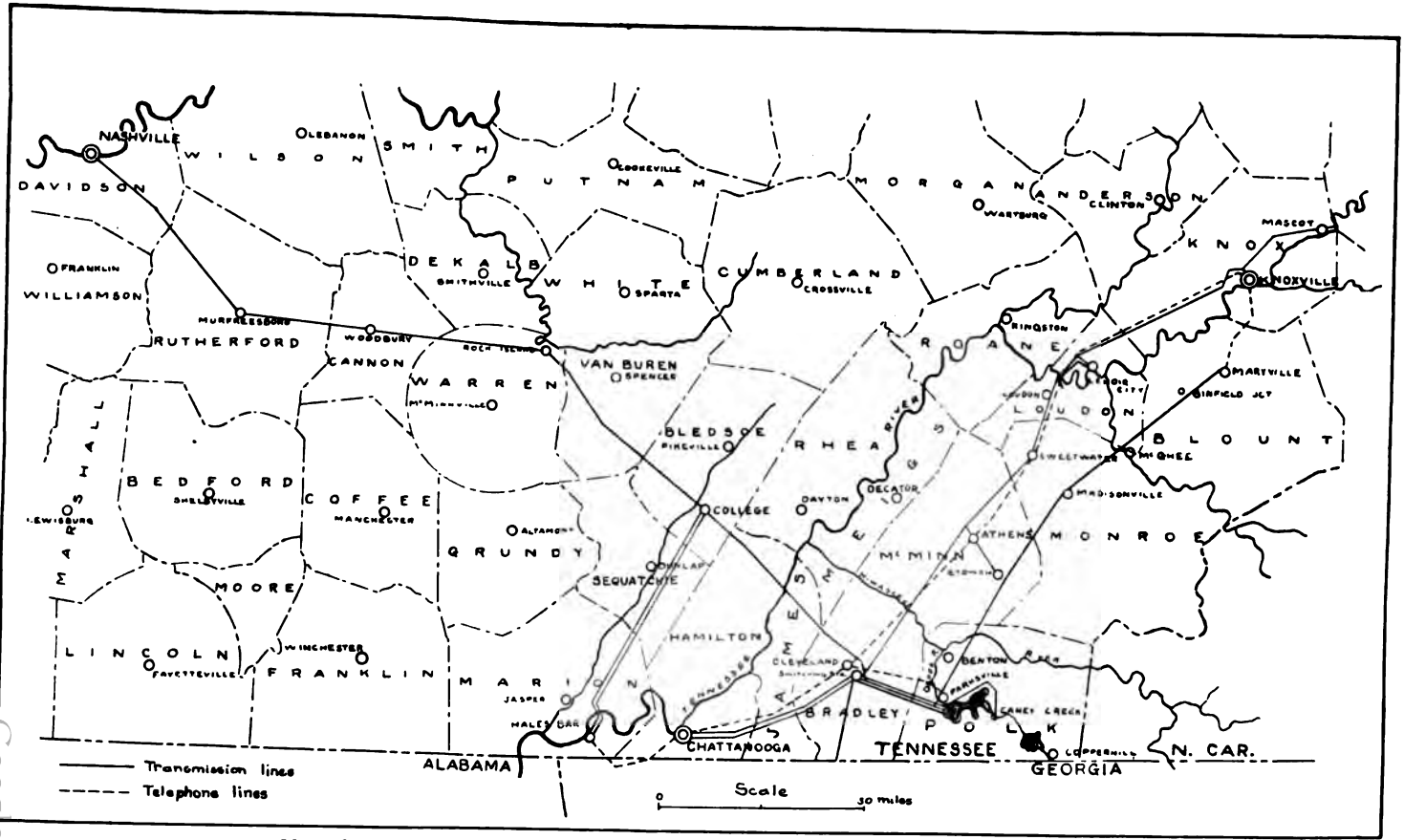
Page 178. Line 29. For "Brecia" read "Breccia".

Page 180. Transfer "Pegram ls. (Mid. Dev.)" to the space just beneath "Hardin ss".

Page 180. In the top space under "Brownsport gr.", insert "Decatur ls".

Page 181. For "Black slate" under "Devonian", read "Black shale".

Digitized by Google



Map showing the power transmission system of the Tennessee Power Company.

Digitized by Google

The Operation of the Hydro-Electric System of Tennessee

By J. A. Switzer.

The average householder, accustomed to his electric lights, seldom gives a thought to the marvel so easily placed at his command. When he presses the electric button the bulb flashes forth into brilliancy with all the certainty of the morning sunrise. When at the end of the month he pays his electric light bill, he pays merely for so many kilowatt-hours of electricity consumed. Or so he thinks. Of the innumerable inventions, the patient researches, the succession of refinements which have contributed to that certainty of operation; of all the multifarious services of men who are merely faithful to their posts; of all the intricacies of mechanism and correlation of parts so vital to the production of those kilowatt-hours; of all these he has but the most vague conception, the most inadequate appreciation—if indeed he has any true appreciation whatsoever.

Nevertheless the harnessing of great water powers, the consequent generation of electricity and the transmission of this electricity to distant places, appeals to the popular imagination as something peculiarly poetic. The thought of a Nashville citizen that the light by which he reads his evening paper comes all the way from the Ocoee River, 153 miles distant, can not be unmixed with wonderment. And properly so, for it is a wonderful thing.

The Tennessee Power Company, which is responsible for the accomplishment of this feat, has now built up a system of power generation and power transmission that is at once extensive and complex; and the purpose of this article is to call attention to, and if possible explain, in a non-technical way, a certain really marvelous detail of the practical working of the system.

First, attention should be called to the map of the company's transmission lines, and the location of the water power developments, and of the steam auxiliary plants. At Parksville and at Caney Creek in Polk County are two water power plants, and at Hale's Bar in Marion County is a third. This last does not belong to the Tennessee Power Company, but to the Chattanooga & Tennessee River Power Company. However, the former company has contracted for a block of 10,000 H. P. from the latter, to be delivered for a long period of years. In order to utilize this power the

Digitized by Google

Tennessee Power Company has built the transmission lines from Hale's Bar to College, the connecting point on the Nashville line, as shown.

The steam auxiliary plants concerned are located, respectively, at Chattanooga, Cleveland, Nashville and Knoxville.

Now, counting the 10,000 H. P. from Hale's Bar, the company's available power from water sources is 55,000 H. P. And this would suffice for all the present needs for power at all the places reached by the transmission lines, if only it were available for 365 days in the year. But unfortunately the bounty of the rivers is strictly limited; for much of the year there is not water enough in them to keep all the water-wheels running, and during the summer dry spell not anywhere near enough. The consequent deficit must be made good by the operation of one or more of the steam-driven generators at one or another of the steam plants, or at all of them if the rivers get very low indeed.

At first sight this might seem all very simple. For example, suppose that at a certain time of a certain day the amount of power to be got from all the water powers should aggregate 20,000 H. P. Suppose that at the same moment the combined *demand* for power at all of the cities on the line were 24,000 H. P. Clearly the deficit of 4,000 H. P. would have to be supplied by one or another of the steam plants; so a 4,000 H. P. steam turbine (or two 2,000 H. P. steam units) would have to operate and pour out 4,000 H. P. of energy into the transmission system, thereby making the supply equal to the demand.

If all this were a problem of supply and demand in dollars or in potatoes, or in anything else in the world than electricity, it would be quite as simple as it appears. Customer A is in the market for 24,000 bushels of potatoes. Merchant B can supply only 20,000 bushels; so he calls on neighbor C to furnish 4,000 more, and everybody is satisfied.

But merchant B and neighbor C do not have to *synchronize* their potatoes. And with electric currents, there rests the difficulty. Two generators to furnish electricity to the same transmission system positively must operate in *synchronism*. In a few words this very technical matter can be made clear.

There are two kinds of electric currents, direct currents and alternating currents. But when electricity is to be transmitted to any considerable distance, direct current can not be used. An alternating current is one that flows throughout its circuit alternately, first in one direction and then in the other. It is constantly pulsing now forward then backward, then forward then backward, with the regularity of a pendulum. At each alternation its strength grows to a maximum, diminishes in value to zero, reverses its direction, again grows to a maximum, again diminishes to

Digitized by Google

zero and again changes direction. The frequency with which these alternations succeed each other is determined by the construction of the generator and *by the speed of its rotation.* A 60-cycle current is one in which the complete cycle of these changes is effected 60 times every second.

Now, if two electric generators standing side by side are both to furnish current to the same transmission line, it should be evident that they must be exactly "in tune" with each other—they must march "lock-step", else they can not march at all. In the terminology of electrical engineering, this fact is expressed by the statement that the two generators must operate in synchronism, or synchronously. And if one generator be first connected to the line (by the closing of a switch), the second may, under no circumstances, be thrown upon the line with it until it has been brought not only to precisely the same speed as the first, but also into synchronism with it. Should the switch which connects it to the line be closed when this condition does not exist, the effect would almost certainly be seriously to injure or even destroy one of the two generators.

The synchronizing of one generator with another in the same room is a delicate procedure. But actually to be able to synchronize one generator with another generator or a group of generators a hundred and fifty miles away, seems little short of wizardry; and indeed it is so. Yet in the daily routine operation of this intricate plant, the tendrils of which now cover so much of the State of Tennessee, all the possible combination and permutations of operating conditions are used. The light on my study table in Knoxville at this moment may come from the coal that burns under the boilers at Nashville, or from the "white coal" that flows through the water-wheels at Parksville or at Hale's Bar. Indeed, there are even more complex possibilities than that; for this transmission system crosses the State line, and at Rome, Georgia, makes contact with the system of the Georgia Power Company, and these two great companies—The Tennessee Power Company and the Georgia Power Company—frequently interchange power. So my light this evening may come from Tallulah Falls!

A mile to the east of Cleveland, out under the silence of the stars, there stands a silent building surrounded by a stockade. From it wires extend to the east, to the north, to the south, to the northwest, and to the southwest. It is the switching station of the system; and here a solitary operator must keep ever alert. The wires are some of them large—the arteries of the system; and some of them small—the nerves of it. These latter are telephone wires; and the operator can instantly communicate with any station operator anywhere on the system. Receiving his instructions by telephone from the office of the chief operating engineer, the switching

Digitized by Google

operator controls the entire system. Upon the wall of the station there is placed a large map of the system. On the map are indicated not merely all of the generating stations, but there is a symbol for each generator in each station. This map is a large and most interesting peg-board. By means of pins having large heads variously marked and colored, the operator keeps before him at all times a graphic portrayal of the existing conditions of operation. When the shift changes, the new operator coming on duty can scan the map and see for himself which generators at each station are in service, what switches are closed and what open everywhere on the distribution system, which cities on the line are receiving power and which are not.

The operation of the system of the Tennessee Power Company illustrates in a concrete way the working of the principle of conservation. Insofar as existing conditions admit, every cubic foot of water flowing in the streams is made to yield up its available energy at the power sites; and when this is insufficient the steam plants are called upon to furnish the balance. A contemplated part of the scheme of the company is the building of a large storage reservoir on the head-waters of the Ocoee River. When this is accomplished, much of the flood discharge which now passes over the dams without conferring any benefit, will be held in reserve until a season of lessened natural flow, and will then be released in such quantities as to yield the maximum of service.

It is no part of the purpose of the present paper to raise any question as to the equitable division of the benefits of this conservation. It is written merely in the belief that readers of "The Resources of Tennessee" are interested to know of the workings of the new hydro-electric industry.

Digitized by Google

West Tennessee Gullied Lands and Their Reclamation

By R. S. Maddox.

INTRODUCTION.

Certain conditions may exist that do not apparently affect society as a whole or any portion of it very greatly, one way or the other; but if those same conditions defeat the people in or hinder them from the attainment of some recognized benefit, or in other words detract from the public welfare, then those conditions are harmful. The development of the country and of each individual community is demanding more consistent and united effort every day. The country's resources have to support a growing population, growing not only in the number of individuals to be fed and clothed, but also in its ideas of what are better homes, better living, better surroundings, better communities.

The opportunities for migration, homeseeking, are far less now than they were even a few years ago. The lands east of the Mississippi River have long ago gone into the hands of private individuals. The present population must rely upon the land that it now has, and although a great deal of waste accompanied the settlement of these lands, as is natural in many pioneer countries, the progress in scientific agriculture, the advancement in education, and the force of necessity, have brought about a demand for more conservative use of our natural resources, and at the same time the improvement of our restorable resources.

Land as a natural resource.—Land is one of our indispensable natural resources. It cannot be exhausted like coal and oil, but because it may be so used as to diminish or destroy its usefulness, it may be called, for all practical purposes, exhaustible. Unlike coal and oil, it may be restored except in rare cases. If it is handled so that its usefulness is partially impaired, it may be to that extent only temporarily exhausted, because it may be restored to its former or even better condition. But if through some agency a portion of the earth's surface is so altered as to cease for always to meet any of the requirements of humanity, then that portion may be called entirely exhausted. The results of the action of natural and human agencies determine whether land can or can not be continuously used most advantageously for man's purposes. The thing of vital importance to

Digitized by Google

humanity is the fertility and productivity of the soil, the maintainance of the earth's surface in a condition such that the maximum area is constantly available for contributing the best to human wants.

Erosion.—Of the many things that tend to injure the soil surface and reduce the productive area, erosion is perhaps the greatest. It does its work slowly but surely. Every stream that becomes muddy from a rain is sure evidence that erosion has been at work. Its activity has varying degrees of intensity, from the torrent of muddy water to the rivulet slightly tinted, but in whatever form it appears, it is doing a sure amount of wasteful work. When the real muddy water is not running in the old gullies or the fresh made ones as a forceful reminder of its stealing away the soil, we have only to look at the thin, worn-out gullied patches and the multitude of gullies of all sizes, to see emphasized the destruction already done, the channels to which it is gradually adding new ones every day.

DESCRIPTION OF LANDS.

All parts of the State contain more or less eroded and gullied lands. In this, Tennessee is not alone. The badly washed and gullied lands in West Tennessee are here under special consideration, and the discussion in this article will refer to those outlined below, unless accompanied by an explanation.

This area lies in a belt extending in a northeast and southwest direction through the State, and is practically contained in the counties of Henry, Benton, Carroll, Henderson, Madison, Chester, McNairy, Hardeman and Fayette. It is not to be inferred that all the lands in these counties are washed. Some portions are badly washed and others not. Some farm land as fine as can be found in the State is contained in these counties, but this is not the portion needing immediate attention. The better lands with a little care taken regularly can be constantly kept good; but the lands that have been washed away and abandoned must have both help and time before they can be made useful again, and their usefulness is being postponed as long as this help is kept from them.

Character.—The land in this belt contains a great deal of sand. In some localities the very sandy soil is the surface soil, and is mixed with enough clay to make it subject to easy erosion, the rapidity depending upon the slope. If the soil were entirely sand, the rain water would soak in rapidly with no surface change perhaps worth mentioning. But the per cent of clay here in mixture with the sand is such that sufficient resistance is given to prevent the water from soaking in as fast as it falls, and therefore on slopes has to find an escape over the surface. In doing

Digitized by Google

so it carries away the soil, leaving the surface gradually impoverished, finally furrowed with gullies, and abandoned. These, in land of this character, have steep banks, often perpendicular, and not infrequently 10 feet to 15 feet deep. In some instances they attain even greater depths. Sometimes they reach what might be called big proportions, being large enough to contain a small house.

In some localities the surface soil has more clay in mixture with the sand than the soil just mentioned, but where this surface clayey soil has been cut through by erosion into the underlying stratum of sandier soil, the banks are steep, assuming practically the same form as in gullies where the surface contains more sand. In the "soapstone" clay in this belt the soil erodes easily also, and the banks cave in. The character of the gullies throughout shows the constituency of the soil to be such as to make it very susceptible to erosion.

Drainage.—The drainage of this land is in two general directions, toward the Tennessee River on the east, and toward the Mississippi River on the west. Since the elevation above sea level is comparatively small and the length of the streams comparatively long, the main streams are rather sluggish and usually have narrow strips of wet, boggy land on either side. The slopes and hills, though, above the river beds and bottom lands, are of varying degrees of steepness, giving rise to sufficiently rapid surface drainage to furrow them with gullies.

Precipitation.—The annual precipitation on this area ranges generally between 50 and 60 inches, and is so distributed throughout the several months that plant life is in very little if any danger from lack of moisture.

Temperature.—The temperature varies between a few degrees below zero Fahrenheit in winter to about 105 degrees above in summer. But since the area under consideration is only between 350 and 600 feet above sea level, and between the parallels of 35 degrees and 37 degrees north latitude, the temperature and precipitation are both favorable to vegetable growth. The atmosphere is generally laden with moisture, which on clear nights is precipitated as dew or frost, except perhaps in the months of July and August, ordinarily the driest and hottest.

History.—In the settlement of this portion of West Tennessee, the history of pioneer countries similar in character has been repeated. It was practically a broad expanse of virgin forests, having little or no market value because of the lack of transportation facilities. Population was sparse, land plentiful and cheap. Timber had to be removed in order to build homes. The homeseeker—the farmer—was the first comer. He

Digitized by Google

was compelled to have land for cultivation. The timber was in his way, and from his standpoint worthless, a hindrance and a nuisance.

The clearing of land that is done under these conditions often goes on for so long a time and to such an extent that it becomes a slaughter of timber, and when this is the practice there is frequently no incentive for the farmer to be painstaking with his land. The wearing out and washing away of his land is of small account, for he can clear up a new piece, rather than continuously be on the guard against depletion from gullies and other means.

The writer has been informed by several of the older residents of West Tennessee, that they have done this very thing—cleared a piece of new ground, cultivated it until worn out, turned it out to waste, and cleared other fields which would be treated likewise when they were worn and washed. As the population became denser and the acreage less per capita, the land necessarily became less exploited, but today a large amount of it in this area is lying waste as a result of its early and destructive treatment, and many places now in cultivation are evidently awaiting a similar fate. Many old fields have gullied places started in them. The land is cultivated up to these gullied patches, and as these encroach little by little upon the cultivated lands, less and less of the field is tilled each year until finally it is abandoned. This often necessitates the clearing of more land, and frequently a big waste of timber which this section can not easily afford; a waste which the present population may not seriously feel, but which will be felt by those of the future.

Besides the land that is being gradually abandoned, we have that which has become badly gullied, and therefore already abandoned, some recently, but a great deal of which has been in that condition for a long time. This is evident from the character of gullies and scattered growth on portions of it. These areas would be inconvenient, hard and profitless to cultivate, if this were attempted at present. Besides, the gullies act as drainage lines that prevent the natural water table from reaching its original height, frequently making it difficult, and sometimes impossible for vegetation to grow without assistance. Where gullies are far enough apart, vegetation of some sort usually occurs.

All of this cleared land now lying waste was at one time evidently productive of farm crops. The composition of the soil being sand and clay with sand very greatly predominating, gives it a characteristic most favorable to easy cultivation. When plowed, instead of becoming "run together" and baked hard after hard rains, as is often the case with heavy clays, its tendency is to remain loose. As stated above, because the soil contains such a large proportionate part of clay, it is rendered very sus-

Digitized by Google

ceptible to erosion, especially with shallow plowing. The preparation of the soil for the crop certainly has played an important part in the history of these waste lands. The custom was to do shallow plowing, frequently using just one horse. This gave only a very thin, spongy surface to catch and hold the rain. The tight dirt could not soak up the water rapidly enough, so put upon the thin plowed coat the work of holding practically the entire quantity of water, which it could not do. If a heavy down-pouring rain came, the chances were all in favor of much of this plowed surface on slopes being washed away. The steeper the slope the more favorable the chances for this disastrous washing. No doubt erosion was often hastened by the way the cotton and corn rows conformed to the slopes. If they were laid off up and down the slopes, they furnished furrows in which the water quickly gathered and easily started to run. In some instances this sort of farming is still being practiced.

FIG. 1. Abandoned land in West Tennessee undergoing the ravages of erosion.

Vegetation on area.—The most abundant and practically all the kinds of plant life, other than trees and shrubs, growing naturally on these abandoned areas, are broom-sedge, "saw-briars", blackberry briers, "poor-land pusley", and Japan clover. Where used for pasture they yield scant grazing in proportion to the area covered by them.

Except where some few shade trees occur at old house sites, the only kind of tree growth on these abandoned old fields is such as have come

Digitized by Google

in naturally. These trees include scattering oak, gum, occasional sassafras, yellow poplar, cedar, black walnut, persimmon, sycamore, dogwood, and sumac. While tree growth of this kind can never perform the function of a forest, either for timber or for protection because of the scanty stand, it is far better than nothing. It also indicates the possibilities of the soil, and may in some cases give a great deal of aid in making dams to start the reclamation of these lands.

Areas are frequently found that are washed completely away; that is, the surface has been lowered into a bed of gullied waste whose bottoms and slopes occupy the whole area. In such places little or no vegetation is growing. They present to the eye only bare, ragged earth, extremely hot in summer and cold in winter.

Estimated acreage—The writer, judging entirely from the portion of the area he has seen, and included within a boundary running approximately through Elkhorn, Paris, Henry Station, Huntingdon, Leach, Milan, Gibson, Jackson, Medon, Bolivar, Hickory Valley, Somerville, Moscow, LaGrange, Saulsbury, Middleton, Selmer, Purdy, Lexington, Alberton, Wildersville, Buena Vista, Camden, Hollow Rock and Springville, thinks that 10 per cent is a conservative estimate of the area actually held by gullies and coming under their influence; and that 25 per cent of the once cleared land is now actually lying out, and furrowed by gullies, abandoned to waste and having only slight vegetation growing upon it. Relying upon the above percentage as a basis from which to estimate, this would indicate that more than 115,000 acres of land once cultivated are now occupied or influenced by gullies, and over 230,000 acres once cleared and cultivated are lying waste, which amount includes the badly washed lands, and old fields which can not be classed as washed away and occupied by gullies, although some few gullies may be present.

Economic value.—The income from such an amount of land would be enormous if it were on a producing basis, whether of farm crops, pasture or timber. Its value for farm products alone, or for stock raising alone, would be almost prodigious. Granting that even the smaller figure represents the entire acreage of abandoned land, if it were on a productive basis of say two barrels of corn per acre, which is extremely small, it would yield 230,000 barrels or 1,150,000 bushels per year. This, at only 50 cents per bushel, would be worth $575,000.00. The same area if put under grazing management would support enough stock to bring an annual return of many thousands of dollars. The product of timber that could eventually be secured from it would of course be classed as a long time investment. But only part of it should be kept for timber. Certainly

Digitized by Google

timber for fence posts should have a prominent place, because that is greatly needed now, and the need will increase with time.

The present condition of these lands is certainly to be regretted; but the fact that all of them have possibilities of being restored in time is a thing to be glad of. Portions of them will take longer than others, but they can be reclaimed. Although some of them are in a very serious condition, none of them have reached the stage from which they can not be redeemed. As they stand today they lower the value of the other lands and often cause a misunderstanding of their possibilities. They should be producing returns of thousands of dollars, but this possible return of value is lost directly to the owners and indirectly to other people. It is true that the owner and State get along without this extra produce, but the main object is not simply to be able to exist without certain additional possession, but constantly to improve and practice a more intensive agriculture, making it a means to an end—better living in its full sense. Each generation that succeeds the other must accept the soil in just the condition in which it is left, and, in order to give recognition to the value of the present organization of society, each one must perform a double duty, that of making the best of what he has, but so as not to injure another, or to impair its usefulness to the next one.

Such gullied lands very frequently affect the public roads, making them both bad to travel and difficult to maintain; in some places the ditches along the road are filled up; in others they are so washed out that the roadbed has had to be changed. Often the heads of gullies work back and make dangerous banks on the roadside. A great deal of benefit is evidently being done the public roads in many places by planting Bermuda grass and wild honeysuckle on the sides of the roadbed proper, and on the banks. The turf and vines prevent the road and banks from washing away, thus saving a big amount of work and expense for repairs. The chances are much in favor of the extension of this sort of road improvement.

The effect of these gullies may be keenly felt where dredging is concerned. Sand is washed readily from the slopes and deposited in the dredged channels, rendering the results less effective and possibly defeating the purpose of the dredging. They may even prevent a dredging operation from being started.

Moral influence.—Not only do these lands yield practically no returns, but they have a moral effect upon the community. Man's nature is affected by his environment, and responds in a greater or less degree to it. His appreciation of better conditions, better surroundings, better lands,

Digitized by Google

increases by fruitful attempts of attainment. But if he allows neglect to creep into his business, he more easily finds excuse for putting off what ought to be done, and it soon becomes the old story of going the way of least resistance. On the other hand the attainment of results develops in him an appreciation of appearance, fitness, and progress. Lands well kept are ornamental as well as valuable, and have a wholesome effect upon both owner and observer; they raise the standard of living, and, by engendering pride and self respect, tone up the moral atmosphere of the community.

Timbered areas needed.—Much of this land under consideration should not have been cleared in the first place. Certain ridges and slopes should have been left wooded, both for the sake of drainage and future timber supply. An area cleared on a slope below a woodland is free from a great deal, if not all of the rapid run-off that would happen if the timber were removed, because the trees, undergrowth, and ground litter hold the rainfall and turn it loose to drain off gradually, but where the entire slope has been cleared, it frequently has little or nothing with which to prevent the water from running off rapidly, causing gullied and surface wash, the open and constant ravages of the soil. These steeper slopes have remained productive farm lands only a few years. They have not met the requirements of agricultural land—uninterrupted production of crops. They have ceased to be useful, and will require a great deal of time to be restored. Short-sighted farming considers only the immediate crops. Farming, to be a success, must not only recognize and preserve its natural timberlands, that is, lands to be kept always for tree growth, but it must recognize and observe the relations between its timbered and its cleared lands.

Remaining timber.—Very little virgin timber now stands within this area. It is practically all second growth, mostly oak and gum, a vast majority of it under 20 inches in diameter on a stump breast high. The kind of posts that are available are short-lived, ranging mostly from seven to twelve years. Trees to produce not only lumber but also posts and poles, must be grown under forest conditions, and not as isolated trees, where so much of the trunks are taken up with limbs which make knotty, rough and weak lumber, or short, rough posts and poles. For this reason the scattering trees found here do not represent a valuable growth for these products. The timber that is used for posts and poles would ultimately fill a better purpose for lumber, if let grow. If some other tree can be grown more rapidly with a much longer life in contact with the ground and at the same time restore the waste land, it would be economy to grow that tree for posts and save the other trees for uses to which they are bet-

Digitized by Google

ter adapted. Besides there is much expense in resetting posts every few years, both in the wear and tear of the wire, and in labor and timber.

Need of reclamation.—At least one assertion can be made with certainty about these gullied lands; namely, they are not likely to become any better than they now are, unless some help is given them. They should not be allowed to remain waste lands for time alone to reclaim. Under some conditions, time by itself will never restore lands nor woods, but will continue to destroy. Such is the case where the slope is steep and the soil shallow with underlying outcropping strata of rock, or in karsted regions. But no such conditions exist within this area. All these gullied lands produced through the agency of man can be brought back to usefulness by planting something on them that will grow and prevent the land from further erosion. Their reclaimed value may probably never equal what it might have been had they not been reduced to their present state. But it is safe to say that any further postponement of starting their reclamation will not increase their chance of having a bigger value when reclaimed later. Nature alone has been doing what she could, but needs all the help she can get. When assisted by man, intelligently directed as we say, she may be made to work profitably and constantly for him.

RECOMMENDATIONS.

For the present the writer is recommending such growths to be used in starting the reclamation of these lands as he observed while on the ground and which seem especially adapted to both soil and climate. These are considered in the following paragraphs:

Need of posts.—The day of the old worm rail fence is gone and gone to stay. Timber is too scarce to admit of such further destruction, and the use of posts is becoming imperative. A tree that will supply a good yield of lasting posts, is therefore desirable.

Black locust.—The black locust is one of the most excellent trees for fence posts; for stopping up gullies and taking hold of thin-gullied areas, the writer knows of no better tree. Men who are acquainted with it pronounce it capable of producing a post at the age of from six to fifteen years, depending upon the character of the soil in which it grows, and the size of the posts desired. It has a massive root system, which is a requisite for holding soil in position. The tree is a legume, belonging to the same family as the ordinary field pea; its roots collect nitrogen from the air and store it in the ground, making the land continually richer. When the tree is cut at the proper time, it will, at the next growing season, send up from its roots and stump a thicket of sprouts that act in the same bene-

Digitized by Google

ficial way upon the soil, and which, in a few years, yield posts. The fertilization of the soil by the roots gives rise to a crop of grass and weeds where an opportunity permits, which is also beneficial in preventing erosion.

The wood of the black locust is hard, compact, heavy, and strong. It has great endurance in contact with the soil, and posts of ordinary size have been known to last from thirty to forty years or longer, in the ground. The U. S. Forest Service, in one of its circulars, gives the life of the black locust post, in average conditions, to be from fifteen to twenty-five years. At any rate they last much longer than those of oak, sassafras and chestnut now in use. The farmer, who has had experience with black locust, knows its worth, and is always willing to put it in the ground for

FIG. 2. **Black locust bushes checking erosion at the head of a gully. The heavy root system is shown where the caving continued until the sprouts got a footing on the bottom and sides.**

posts, because of its lasting qualities. Enough black locust is found here and there throughout this section to demonstrate the practicability of growing it.

Cows are exceedingly fond of the leaves and young sprouts, and horses will also eat the foliage and tender twigs. For this reason the young trees must be protected from stock, at least until they get out of reach.

The locust does not necessarily wait until cut before putting up sprouts from its roots. Often a growing tree is seen surrounded by a thicket of

Digitized by Google

its own sprouts, and this habit makes it especially valuable for stopping gullies. It is not particular about soil and moisture, but like most other vegetation it grows best on rich, moist soil. But as stated before, it takes hold of and grows on poor soil and builds it up. Wherever a thicket is cut off for posts it is advantageous to the new crop of sprouts, if the land can be plowed before they come up. It can be grown from either the seedlings, sprouts or seed. Many opportunities are offered on this area for starting a black locust thicket or grove. The seed can be sowed broadcast, or in rows, or the sprouts and seedlings can be set out. The condition of the West Tennessee gullied lands will not always permit a regular spacing of the seedlings, but for making a grove a good spacing is six feet apart, or as is recommended by the United States Forest Service, a spacing of six feet apart in rows four feet apart. Although winter time may be chosen for setting out the plants, the very early spring is recommended for both planting and seeding.

Yellow poplar.—The yellow poplar within this area shows excellent growth and ease in reproduction. It is found coming in on the old fields amid gullies and frequently right in the gully bottoms. It does not have sprouting ability like the locust. It sprouts not at all from the roots but occasionally from the stumps if the tree is cut when small, but such sprouts do not amount to much. It makes a valuable timber tree when grown with other trees, so as to make it prune its limbs and grow a long, clear trunk; but in the open it has a relatively short trunk, full of limbs. In gullies, it affords a check to erosion by catching up dirt and giving weeds and grass a chance to get a foothold. The writer has seen this tree in the area mentioned, attain, at the age of twenty years, a height of 70 feet, and a diameter inside the bark of 16 inches on the stump two feet high. On this area it is not found in a pure stand, but occurs either singly, or just a few in a group among other trees. The indications are from natural reproduction found under such conditions that artificial reproduction (reproduction secured by man's sowing seed or planting seedlings) would be easily obtained. Some preparation should be made for planting the seed or seedlings. Small dams should be put in the gullies, and the seedlings set out above, or the seeds sowed and lightly covered. If nature with this assistance, does her work as well proportionately as she has unassisted, a most excellent growth of young poplar should soon come on.

The spacing of the seedlings, if planted, should be about six feet apart, and as they become larger and get in each others' way, such thinnings should be made as would maintain the density of stand sufficient to cause the tree to throw off its under limbs and grow a long, clear trunk.

Digitized by Google

Black walnut.—Black walnut is also found growing promiscuously throughout this area on both poor and good land. It grows well on good soil, but poorly on thin soil. It makes the choicest of lumber, and as everyone knows, yields a very edible nut. It can be made to grow in the bottoms of gullies by planting the nuts above small dams which keep them from washing away by holding the soil in place, so the seedlings can get a start. The mouth of a gully is a good place to plant the black walnut, especially where the gully ends by spreading out. Such a situation affords both

FIG. 3. Showing yellow poplar growing in the bottom of a gully. Such is rather common in West Tennessee.

moisture and fertility. The black walnut does not reproduce from its roots, but will, if cut before it becomes old, sprout from the stump. Such sprouts, however, are usually of little importance. The same spacing should be used for the walnut as for the poplar. The black walnut from the lumber standpoint is scarce, but where it attains a merchantable size, it commands a good price.

Digitized by Google

Sycamore.—The sycamore occurs quite abundantly and apparently has little difficulty in starting in gullies from the seed. In many places it has done a great deal of good by checking the caving in of gully banks, as well as erosion in their bottoms. It has a heavy root system and makes a rapid growth in good soil. The stump is often very hard to kill, owing largely, no doubt, to the season in which the tree is cut. When it is not killed by cutting the tree, the stump sends up vigorous sprouts, but it does not reproduce from the roots. The sycamore at present is not considered in the market a very valuable tree, but since it appears to reproduce so easily in gullies, its value may be considerable in helping to fill them up. The seed grows in balls that are familiar to almost everyone who has seen the tree, and can be easily obtained. Scattering the seed in gullies with a little care and precaution should secure at least as good results as where seedlings come up from sewing by the wind, and with no preparation of the ground for receiving them.

Japan clover.—Japan clover is often referred to as an excellent plant for stopping gullies. It occurs almost everywhere, and helps keep a ground cover on the unwashed lands, and where obstructions occur in washed places. But its root system is not sufficient to maintain itself where erosion goes on uninterrupted. It grows at the mouth of gullies where they run out onto a more or less flat surface, and on soil that has lodged. In order to stop wash from above, a dam should always be used if Japanese clover is desired to get a foothold in the gully, and even then it will wash out when the dam gives way.

Wild honeysuckle.—Wild honeysuckle is an evergreen vine and takes root along the runners as they advance. It forms a perfect mat of vines and roots that cover both sides and bottom of gullies if it is planted there. It can easily be started by taking a few cuttings, and setting them out in the bottom of a gully. Like the other plants mentioned above, it needs some obstruction below to hold the soil until it secures root hold. There is little or no danger of its being washed out after it has secured a footing. In addition to its value in stopping gullies, it affords some grazing for cattle, chiefly in winter when green foodstuff is scarce.

Bermuda grass.—Bermuda grass makes one of the most perfect turfs, and for this reason is most valuable in maintaining a root hold in a difficult situation. It is tenacious of life and stands a great deal of dry weather. Its runners take root at every joint that comes in contact with the soil. It furnishes an excellent pasture for cattle, horses, and sheep. Its ability to make a strong turf, stand dry weather, grow on unfavorable sites, and yield pasture, gives it a big value in the reclamation of gullies.

Digitized by Google

It can be easily started from both seed and turf. In transplanting, it is always advisable to put an obstruction of some sort just below where the grass is set so that it may be assisted in getting a root hold before the rain carries it off. After the roots are fixed, there is rarely ever any danger of its washing out. As the grass catches the dirt washed down, it may sometimes be covered up, but if the dirt is not too deep the grass sends up new runners through the settlings and continues to spread and mass its roots.

Fertility of soil in gullies.—The dirt from gullies is often not understood, is considered poor and not capable of growing anything. Such an idea can be easily changed by noticing the thrifty growth in a gully just above a dam. The dirt in which this vegetation appears consists of that caught from the side and bottom of the gully and held in place by the dam until its properties can be utilized. This soil has never been exhausted nor drawn upon by roots of previous crops, and only needs holding in place, and moisture, to afford it an opportunity of giving up its potential fertility to plant life.

Since it has been advised that the above mentioned plants be set out in the bottom of the gullies, mention is made here of the quality of this soil, because it will naturally and necessarily become the source of food for them. By putting in some sort of dam a soil full of nutrition is furnished the growth set out. Many like instances can be seen in the growth of weeds, briers, grass, bushes, and trees in the bottoms of gullies, where the soil has caught.

Throughout this section, farming and stockraising are the chief occupations. The land is primarily agricultural and should be looked after in that capacity. Immense numbers of cattle, horses and sheep, not to mention hogs and goats, could be raised if the gullies and waste lands were reclaimed for which they are capable. Two valuable results for the land alone would be accomplished, if it were used in this way. First, it would all be made productive. Second, it would be removed a long way from danger of further waste because of the hard lesson of experience.

THE STATE'S INTEREST IN RECLAMATION.

The landowner is always more prosperous when his farm can be made to produce both good crops and stock. The landowners compose the communities, and the communities compose the State. The welfare and relation of each to the other is so closely linked as to compel the recognition of their inter-dependence. It is to the interest of the State to encourage, at least by approval, everything progressive and beneficial, and in

Digitized by Google

some cases by actively aiding where aid is needed, and is possible. Although title to the land is held by the citizen, the State is benefited by its productiveness, and is prosperous just in proportion to the prosperity of its citizens. If the State owned the gullied land, its duty would be to make it of the most value possible, experimenting at first but finally arriving at a definite course to pursue for its reclamation. But since the State has given its citizens the right of ownership, it still has an interest in encouraging the appreciation of this ownership, a term that means the right to use but not to waste.

Digitized by Google

The White Phosphates of Tennessee

By J. S. Hook.

White phosphate rock was first recognized in Perry County, along Toms Creek, in 1896, by prospectors familiar with the similar "hard rock" phosphate of Florida. This was after both the blue-bedded phosphate, and the brown residual phosphate derived from Ordovician limestones, had been discovered, and while extensions of these latter fields were still being actively sought. White phosphate was soon noted along various other creeks tributary to both the Tennessee and Buffalo rivers, in northern Perry County. In 1901 active prospecting disclosed an extension of the white phosphate field across the Tennessee River, westward in Decatur County. So far as known, no other deposits comparable to those located within Perry and Decatur counties have been discovered.

Varities of the White Rock.

The deposits in Perry County were early studied by Dr. C. W. Hayes, whose observations are to be found mainly in contemporaneous publications of the United States Geological Survey.* Hayes recognized three varieties of the white rock, and adopted a classification based on what seemed to be the evident method of deposition, as well as on the physical structure of the rock. His three varieties are (1) "stony" phosphate, consisting "of a siliceous skeleton, the cavities of which were originally filled with lime carbonate, but are now filled with phosphate. The latter form from 27 to 33 per cent. of the rock". This variety represents substitution by replacement, of calcium phosphate for calcium carbonate in an originally siliceous limestone. (2) "Breccia" phosphate, which "occurs in irregular masses composed of small angular fragments of * * * * chert embedded in a matrix of phosphate of lime. The chert fragments vary in diameter from a fraction of an inch to 3 or 4 inches. * * * * The phosphatic matrix, when unstained by exposure to the weather, is generally white or slightly reddish, and rather soft, somewhat harder than compact chalk. When taken from a few feet below the surface, where it has not

*U. S. G. S., 16th (1895), 17th (1896) and 21st (1901). Annual Reports of the Director.

Digitized by Google

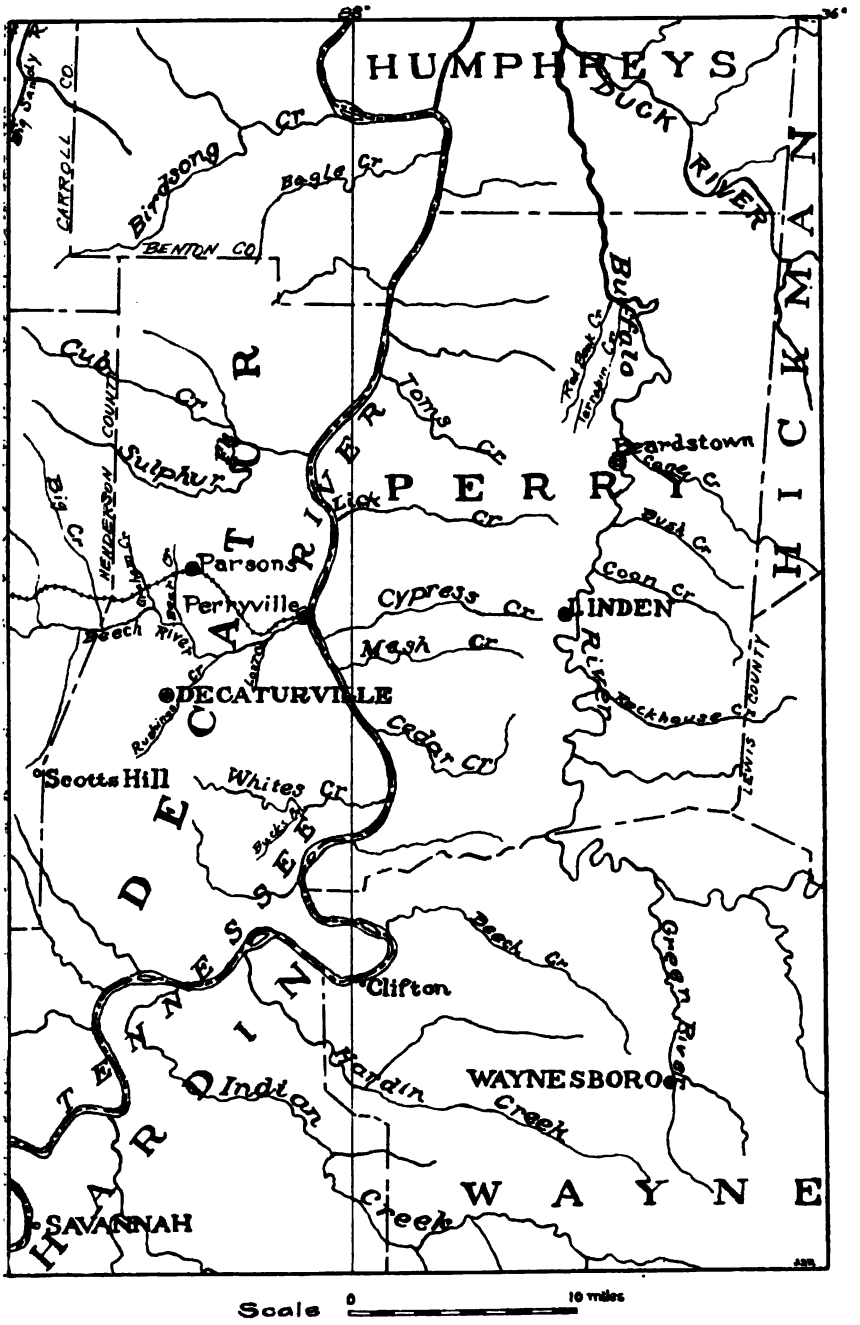


FIG. 1. Map of the white phosphate region of Tennessee.

Digitized by Google

been exposed to the air, it is easily crushed, and the chert separates, so that but little phosphate adheres to it". (3) "Lamellar" phosphate which, "as its name implies, consists of thin parallel layers or plates, * * * * evidently formed by deposition from solution, successive layers slightly different in color and texture." This variety has been of most importance from an economic standpoint.

All these varieties represent but different phases of accumulation by percolating and flowing underground water, the difference between the breccia and lamellar varieties being a purely physical one, while the stony variety is unlike the other two, in that it is essentially a replacement deposit.

Because of the physical features surrounding the occurrence of the white rock, the extent of these deposits has not even yet, after many years since their discovery, become fully known. And it is not probable that complete information regarding its distribution will be available until much systematic and necessarily detailed and expensive prospecting is done in the field. The limits of the territory in which white rock may be reasonably expected, are, however, fairly well known, and may be delimited as Decatur County and the northern part of Perry County.

Associated Sedimentary Rocks.

The rocks of this region form a part of the western flank of the Nashville dome. The phosphate rock is directly associated with Silurian limestones, and with breccias from the Camden chert, though the complete generalized section includes rock from the Ordovician to the Cretaceous. The latter form a thin covering of rounded water-worn pebbles, which may be seen on some of the highest ridges, especially westward from central Perry County, and have been noted at several localities in the vicinity of Hohenwald, with a thickness of thirty feet.*

The general geology of western Tennessee has been the subject of much careful investigation, and in the immediate vicinity of Decatur and Perry counties especially by Pate and Bassler,† and Dr. Foerste.‡ Toward the top of the Silurian a large proportion of the rocks are massive, coarse-grained limestones, and are of special interest in connection with the white phosphates. The Decatur formation consists of a crinoidal limestone which is 70 feet thick in the vicinity of Decaturville. A fine exposure may be seen about a mile and a half north of the town, at Tuck's grist mill, where

*Bruce Wade, "Resources of Tennessee", Vol. IV, No. 4, p. 173. 1914.
†Proc. U. S. Nat. Mus., Vol. XXXIV: 407-432. 1908.
‡Jour. of Geol., Vol. XI: 554-715. 1903.

Digitized by Google

the pike between Parsons and Decaturville crosses Beech River. This limestone overlies shales of the Beech River formation, the latter passing beneath the river. A precipitous bluff is produced by undercutting due to the action of the river at this point. Here may be observed the results which are likely to follow when limestones, especially those which have been jointed, are subjected to the dissolving action of ground water; namely, the formation of solution cavities, enlarged joint planes, caves, etc., which ramify the limestone with intersecting passageways. Along Toms Creek, in Perry County, these are especially well developed.

The Decatur limestone has been observed at Whitfield, in Hickman County,* and westward and southward at various points between Whitfield and Decaturville, and Whitfield and Clifton, in Wayne County. It is evident, from intervening areas, where the Decatur formation is absent, that its removal was effected during a period of erosion previous to the deposition of the overlying Devonian rocks.

The general section of the rocks of the Devonian period includes the basal Linden formation, with a maximum thickness of 35 feet, which in its lower portions is a massive crinoidal limestone, passing upward into more thinly bedded limestone, intercalated with bluish shales. This formation is followed by the Camden chert, with a thickness of 50 feet or more, consisting of an extremely siliceous limestone which, upon weathering, produces a mantle rock containing many angular bits of chert. Where the Camden outcrops on the sides of the hills, there is a pronounced tendency for this type of soil to work its way down the slopes, or to "creep", covering the outcrops of underlying formations.

The Camden chert was followed by the deposition of the Hardin sandstone, a compact, gray sandstone, with sandy shales, which reaches a thickness of 10 feet. The Hardin sandstone is unconformable with the Camden chert, and is separated by still another unconformity from the overlying Chattanooga formation.

The Chattanooga formation consists, at its base, of the blue-bedded phosphate, well developed eastward of Perry County, as along Swan Creek. It gradually becomes less phosphatic westward, in the region of the white rock. The upper part of the Chattanooga is composed of the Chattanooga shale, a black, fissile, carbonaceous shale.

Preceding the deposition of the overlying Carboniferous rocks, there was considerable reduction of the land surface, during a period of elevation and erosion, which marked the close of the Devonian period. Much

*Pate and Bassler, loc. cit., p. 416.

Digitized by Google

of the Chattanooga formation was at this time removed. In western central Perry County the Carboniferous rests on the lower Devonian.*

Physical Relations of the White Phosphate Deposits.

The association of each of the three varieties of phosphate with limestones, and especially those which are susceptible to the formation of caverns and irregular solution channels in them, is a salient feature in connection with these deposits. The lamellar variety is found filling pre-

Fig. 2. Showing replacement of original limestone, shell structure being retained. Lamellar rock deposited later. Natural size.

*Wade, loc. cit., p. 176.

Digitized by Google

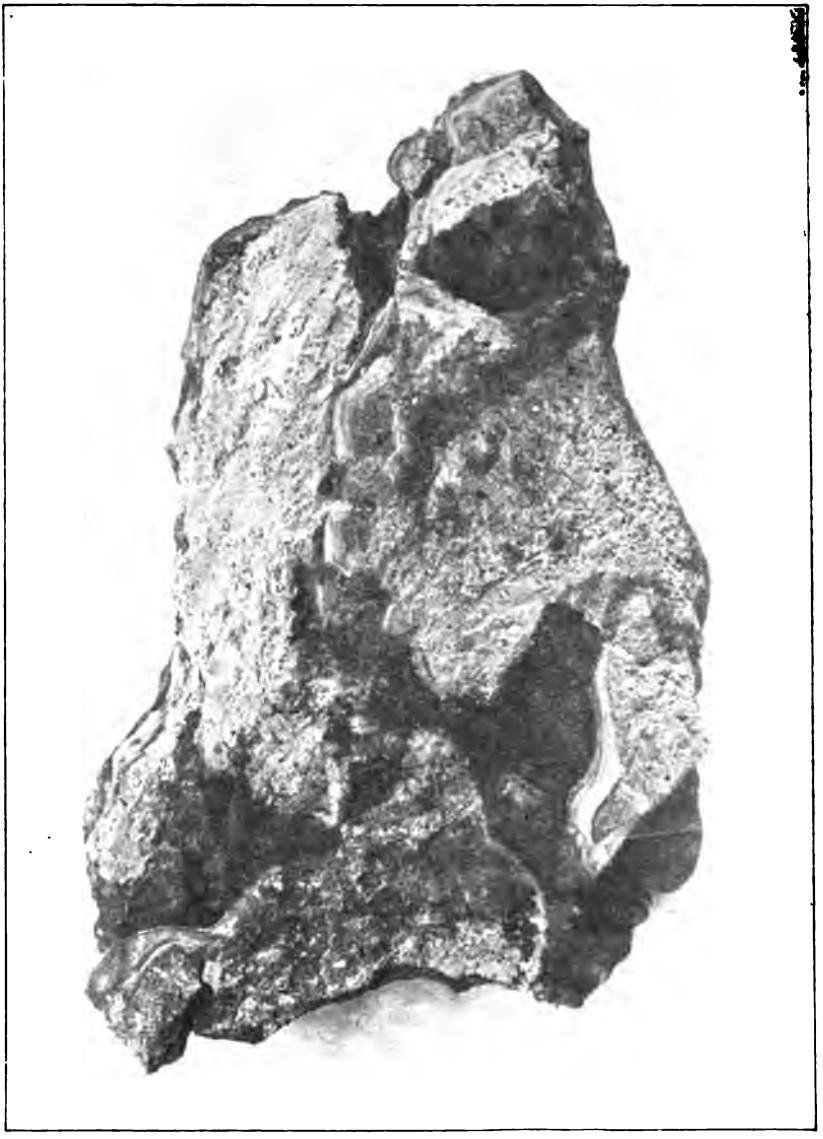


FIG. 3. Brecciated variety of phosphate rock, showing angular chert fragments, cemented together by calcium phosphate. Natural size.

Digitized by Google

existing solution channels, and as a matrix around angular chert fragments at the surface. The phosphatic solutions have also replaced the original limestone, completely retaining the shelly structure of the limestone.

The stony variety of the Terrapin Creek district is evidently mainly a replacement of carbonate by phosphate in beds of siliceous limestones, such limestones being unfavorable for the formation of solution cavities.

When the irregular and uncertain character and extent of these limestone solution cavities is considered, it may be realized that in the white deposits there can be but little regularity in the shape and size of the individual occurrences. Unlike the systems of jointing in much of the region where the brown rock deposits have developed, where the cutters in which the phosphate occurs trend mainly in one direction, paralleling one another at fairly regular intervals, the jointing of this region is less uniform. Consequently there is not much uniformity in the distribution and arrangement in the channels which are simply the enlargement of these joint planes.

These conditions account for the uncertainty attending any postulations with respect to the areal extent and size of the individual deposits of the white rock. Prospecting is made expensive, and the necessity for the most detailed determinations is apparent.

Breccia deposits are surficial masses consisting of chert fragments, cemented by a phosphate matrix. These grade into the lamellar variety as has been shown by mining operations. The lamellar variety is the more abundant, and least contaminated by chert fragments. It naturally follows the sinuous openings within the limestone.

E. C. Eckel* has noted exposures 18 feet in thickness, but considered the average to be about 5 feet in the Beech River tract, in Decatur County, while a 30-foot exposure has been recorded by him as having been reported. The rock from this pit averaged 75-77 per cent. bone phosphate of lime.

According to T. Poole Maynard† the white lamellar phosphate of Beech River district occurs as a sort of blanket deposit, as well as in fissures and caves,—a point of considerable interest bearing upon the origin and mode of deposition, as pointed out in his paper.

The lamellae of the white rock present various shades of color other than the white, generally brown or reddish, due to content of iron oxides in the depositing solutions. In small cavities left throughout the rock,

*Bull. U. S. G. S., No. 213, p. 425, 1903.

†Res. of Tenn., Vol. III. No. 3, p. 164, 1913.

Digitized by Google

the mammillary exterior surface may be observed, as shown in one of the illustrations accompanying this paper.

The stony variety found in the Terrapin Creek district in north central Perry County is low grade and of minor importance. The replaced siliceous limestones alternate with layers of chert.

FIG. 4. Lamellar phosphate showing mammillary surface produced by deposition in cavities. Natural size.

Digitized by Google

Origin of the White Rock Deposits.

That the white rock phosphates were deposited from percolating solutions, there is no question. The mammillary surface of the rock and its laminated structure result from well understood conditions. Hayes suggested that the source of the phosphate in the depositing solutions was Devonian rock, and according to Maynard the accumulation of the white rock was, in part at least, at a time when both the Devonian rocks and the Upper Silurian limestones were undergoing weathering and erosion, though Hayes has considered that they are at least as late as Tertiary in age.

The solubility of phosphate in acidulated surface waters has received considerable attention from an experimental standpoint. C. L. Reese* showed that in the case of certain swamp waters from South Carolina, calcium phosphate was dissolved when organic matter was present to furnish organic acids. It was also observed that when these same solutions containing the phosphate stood for a time over marl, an unconsolidated calcareous rock, the phosphate was precipitated from solution. The author offered these phenomena as an explanation to account for the nodular phosphate of South Carolina which overlies marly deposits. E. H. Sellards† enlarges upon the observations of Reese by stating that "calcium phosphate taken into solution by the soil waters at and near the surface may be thrown out of solution in case the water stands for a time at a lower level in the earth on or over limestones", and suggests this as a factor in the formation of the "hard rock" deposits of Florida.

That the white rock of western Tennessee owes its occurrence to the operations of such reactions seems very certain. The source of the phosphate has been attributed by most geologists who have studied the field evidence to be overlying Devonian formations. Maynard believes this to have been possible in the case of the Beech River deposits.‡ From the fact that the Devonian has been reduced to but a portion of its original thickness in many parts of the area over which the white phosphate is distributed he suggests subaërial deposition for part of the white rock. In northern Perry County Wade § suggests that the absence of Upper Devonian rock is due to a period of erosion preceding the Carboniferous. Conditions which have been shown favorable for solution and deposition of phosphate could have obtained during post-Devonian erosion. If con-

*Am. Jour. Sci., 3rd ser., Vol. 43, pp. 402-406, 1892.
†Bull. Am. Inst. Min. Engr. No. 93, p. 2383, 1914.
‡Loc. cit., p. 164.
§Loc. cit., p. 169.

Digitized by Google

centration took place mostly at that time, it would place the age of the deposits much older than the Tertiary. Some of the deposits, especially those of the breccia variety, seem to have a close relation to topographic conditions not greatly different in configuration from those of today, and it would not be unreasonable to suppose that the brecciated variety, being a surficial type, grading into the more massive lamellar type, is of later origin, derived perhaps from the lamellar rock itself by resolution and redeposition at the surface, forming a matrix consolidating the cherty mantle rock.

It is not necessary, however, to consider the white phosphates as the result of pre-Carboniferous weathering, for in limestone regions, underground waters may travel long distances through open channels in a relatively short time. The writer does not think the field evidence warrants the belief that any of these deposits "have resulted from direct sedimentation" if by that is meant subaërial deposition under swampy or other purely surficial surroundings. Accumulation under such circumstances is generally attended with contamination with foreign substances, such as the remains of organic life, either plant or animal. The Tennessee deposits are especially free from these.

The essential points in connection with the solution and deposition of the phosphates in the white rock deposits were recognized by Hayes in his early reports. It is not so much a matter of depth at which the chemical reactions take place, except insofar as the general circulation of the ground-water is affected by topographic conditions, as it is one of association with the proper chemical conditions, and the relation of the sedimentary rocks with respect to one another and to subterranean circulation. The deposits can not be expected to have much vertical range, and therefore will not be found to exist in depth.

Distribution.

Perry County.—The Toms Creek locality was the first to be developed and the only one in Perry County which has to this time proved of commercial importance. This creek flows westward into the Tennessee River, and active mining operations were carried on about four miles from its mouth, but nothing has been done for a number of years, so that the openings have become filled with debris.

At first the breccia variety appeared to be the more abundant rock here, but early in the development this proved of minor importance as the operations extended further into the hillsides, where the lamellar variety was

Digitized by Google

met. The phosphate occurs at the base of the Camden chert, and in the underlying Silurian limestones.*

There are several other creeks flowing into the Tennessee River roughly parallel with Toms Creek, and the white rock has been noted along these also. They are Spring and Lick creeks to the south of Toms Creek, and Roan Creek to the north of it.

The rock mined in Toms Creek was hauled about four miles to the Tennessee River and shipped in barges. As is the case with most of the lamellar variety of the white phosphate, the quality was good, but there are apparently economic conditions which prevent the successful exploitation of these deposits at the present, and which caused them to be abandoned, at least temporarily.

The Terrapin and Red Bank creeks district is drained by these two creeks, which flow northerly into the Buffalo River in the northeastern part of Perry County. The stony variety occurs here, outcropping around the borders of the valleys. As the phosphate is so intimately associated with chert and cherty limestones, it is rendered low grade and will probably never be of any commercial importance. The phosphate is associated with Carboniferous rocks, presumably the Fort Payne chert. Similar deposits occur near Beardstown.

Decatur County.—The Beech River phosphate district includes deposits along Bear and Graham creeks; along Rushings and Lost creeks; and also along the Beech River itself near Decaturville. This last named stream is a tributary of the Tennessee River, entering it from the west. The prospected lands of this district aggregate over six thousand acres and are all under the control of the Beech River Phosphate Company.

All the phosphate of this district is associated with the Decatur limestone, extensive openings having been made chiefly near Tuck's mill, one and one-half miles north of Decaturville, from which point some rock was shipped. The rock is both brecciated and lamellar, mainly the latter.

The White's Creek district is to the southeast of the Beech River district and is under the control of the same company. Prospected lands cover more than two thousand acres. The principal openings have been made along Buck's Branch and on the Yarbro place. No active mining has ever been done in this locality.

Phosphate is also known to occur along Cub Creek in the northern part of Decatur County, and has been exposed by prospecting in several places. Too few openings have been made to determine the extent of the white rock in this locality.

*Wade, loc. cit., p. 169.

Digitized by Google

News Notes

The Geological Commission met Tuesday, December 22. The matters brought forward by the State Geologist were discussed and approved. These included: (1) The work accomplished by the State Geological Survey during the last year; (2) the work that demands future attention; (3) the appropriation to be requested at the next General Assembly.

Messrs. H. D. Miser and G. H. Girty of the United States Geological Survey were in Middle Tennessee for several days last November. During their stay they worked out the stratigraphic relation of certain Mississippian rocks of the Highland Rim. The work was done in connection with that of the Waynesboro quadrangle, which is now under preparation.

Dr. L. C. Glenn spent several days during November and December in the Cumberland Mountains, estimating the coal tonnage of the State Mines at Petros. While in that part of the State Dr. Glenn also did some field work for the new State geological map.

Mr. C. D. Isom, temporary assistant on the State Geological Survey, is stationed at Roberta, Scott County, for the purpose of taking samples of the rock removed from wells which are now being drilled there for oil. Samples thus obtained at intervals of every few feet give valuable geological data, which may not be obtained otherwise.

The new State geological map, compiled and prepared by Olaf P. Jenkins, Assistant Geologist, has been finished, and is now ready for publication by the State Geological Survey. The scale of this map is eight miles to the inch. In size it is five feet long, and fourteen inches wide. Twenty-two distinct geological groups are represented by different colors in this work, and the positions of numerous smaller formations, too minute for accurate mapping, but described by various other geologists, are indicated in a descriptive legend that accompanies the map. With these there is a very small map which represents the sources of information, and indicates who did the field work in the various regions. Besides this, there are four sections across portions of the State, which show the structure of the rocks.

Numerous questions naturally arise as to the use of the new State map. It will be of greatest value to those who take the trouble to study it with care, but it will be especially helpful to the person who has some knowl-

Digitized by Google

edge of the science of geology and its application. In the first place it gives a comprehensive view of the physical features and divisions of Tennessee. Then, too, the geology shows and explains in a general way the topography of the State. Such knowledge is of constant service to railroads, road builders, engineers, and agriculturists. A comprehensive idea of the structure of a region, gained from the study of both the map and its cross sections, is of great economic importance to the geologist, miner, and engineer, as well as to many others. As a general mining and mineral map it will be of value, although this is not its primary purpose. Its usefulness in this respect lies in the fact that certain minerals, coal beds, building stones, road materials, etc. are known to occur in certain formations. The map shows the distribution of the formations, and thus will help those who are searching for such material. Thus the map will increase in its usefulness as time progresses, and as new things of economic value are found in the earth. To the farmer the value of the map lies chiefly in its representation of the different kinds of rocks, and, accordingly, kinds of soils.

As a contribution to the science of geology, it is hoped that the new map will be an important piece of work. It will stand, no doubt, as a basis for further detailed scientific study of the State. It must be borne in mind, however, that a general map of the whole State, unless tremendously large, can not show the details of certain small regions. Such minute detail on large scale maps of small regions is for further work, which is constantly being carried on. The value of such work is increasing all the time with a general progress of the industry of the State.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Digitized by Google

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

Digitized by Google

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

Digitized by Google

Vol. III. No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

Vol. III. No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

Vol. III. No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue. Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

Digitized by Google

TN
24
T2
A4

Volume V APRIL, 1915 Number 2

Tennessee. Geological Survey, 19.

THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY, AND OCTOBER
BY THE STATE GEOLOGICAL
SURVEY
NASHVILLE, TENNESSEE

A Magazine Devoted to the Description, Conservation, and Development of the Resources of Tennessee

CONTENTS

Physiographic Influences in the Development of Tennessee.....L. C. Glenn
Care and Protection of Forests.....R. S. Maddox
Two Natural Bridges of the Cumberland Mountains.....W. A. Nelson
News Notes.
Publications of the Geological Survey of Tennessee.

Entered as second-class matter January 10, 19 13, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

Volume V **Number 2**

APRIL, 1915

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey

NASHVILLE, TENNESSEE

STATE GEOLOGICAL COMMISSION

Gov. TOM C. RYE, *Chairman*

DR. BROWN AYRES, *Secretary*
President, University of Tennessee

CAPT. T. F. PECK
Commissioner of Agriculture

DR. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

GEO. E. SYLVESTER
Chief Mine Inspector

GEOLOGICAL CORPS

A. H. PURDUE
State Geologist

OLAF P. JENKINS
Assistant Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

CONTENTS

Physiographic Influences in the Development of Tennessee.....L. C. Glenn
Care and Protection of Forests.....R. S. Maddox
Two Natural Bridges of the Cumberland Mountains.....W. A. Nelson
News Notes.
Publications of the Geological Survey of Tennessee.

Digitized by Google

Looking westward from Bon Air on the Cumberland Mountains, into the Central Basin.

Digitized by Google

TN
24
.T2
A4

Corrections

In Vol. V, No. 1, make the following corrections:

Page 27. Figure numbered 2 should be 4.

Page 28. Figure numbered 3 should be 2.

Page 30. Figure numbered 4 should be 3.

Digitized by Google

Physiographic Influences in the Development of Tennessee

By L. C. GLENN.

INTRODUCTION.

Purpose of paper.—It is not primarily the purpose of the following paper to describe in minute detail the physiographic features of the State, but rather to set forth these features only in sufficient detail to show their relationship to man's activities. The physiographic description will in general be limited to such features and details as bear especially on the development of the State. Perhaps no state is divided into more sharply delimited and strongly marked physical features than Tennessee, and those who desire primarily a description of these features will find them very clearly presented in Safford's *Geology of Tennessee.* Safford's discussion was written before the days of modern physiography, and yet he shows the relation that the physical features bear to the character of the rocks and their structure in a way that could hardly be improved upon by a modern physiographer.

Physiographic regions.—The surface of the State may be divided into six physiographic regions, which are as follows:

1. The Appalachian Mountains, a narrow barrier on the eastern border.
2. The Great Valley of East Tennessee, a broad depression containing a succession of parallel ridges and valleys.
3. The Cumberland Plateau, a broad barrier region.
4. The Highland Rim or Plain.
5. The Central Basin or Plain.
6. The West Tennessee or Gulf Embayment Plain, subordinate to which may be noted the western valley of the Tennessee River and the flood plain of the Mississippi. These regions will be discussed in the order above given.

APPALACHIAN MOUNTAIN REGION.

General description.—The eastern boundary of the State is formed by the crest line of a linear series of ridges that extend from Georgia to Virginia and beyond. These ridges are usually sharply defined, steep-sided, rough and very sparsely settled. They attain heights of 4,000 to 6,000

Digitized by Google

feet in parts of the course. From these ridges on the boundary line numerous spurs project westward, in some places for a distance of 10 to 20 miles into the State of Tennessee. These spurs are separated usually by steep, narrow valleys, many of which end in secluded coves well hidren among the ridges. The region as a whole is a great barrier that has always limited or prevented communication across it, save in certain favorable places.

History.—The first whites to enter the State from North Carolina were hunters who followed the buffalo and Indian trails across these mountains into East Tennessee. Somewhat later, as settlers began to follow the hunters and explorers, these trails became the routes by which they, with

FIG. 1. Typical view across the Great Valley of East Tennessee near Jonesboro. Unaka Mountains in the distance.

their pack horses, crossed the mountains, and until near the close of the eighteenth century they were the only lines of communication with North Carolina. Just before the close of the eighteenth century a wagon road was built down the French Broad River, which cuts across this wall of mountains in a deep, narrow gorge. Since then a few other highways have been constructed across these boundary ridges, but they are usually steep and rough and difficult to travel, and are not greatly used. A number of rivers rise in western North Carolina and flow westward across these high ridges in deep and narrow gorges that are usually so rough and wild that they have generally been avoided by the few highways that

Digitized by Google

also cross them. The road down the Nolichucky River leaves the river before it enters the gorge in the Unaka Mountains, and crosses through Indian Grave Gap at an elevation of over 3,200 feet. The roads down the Big Pigeon, the Little Tennessee and the Hiwassee, likewise leave the rivers and climb across the high ridges on the State line. The only avenues for railway communication from North Carolina to Tennessee are along the river gorges that are cut through the mountains. The first railway to cross this eastern boundary was the one down the French Broad River from Asheville to Morristown, and for years it was the only railway that made the crossing. More recently a railway has been built along the Doe River into, but not entirely across, the western North Carolina mountain belt; another has been built through the gorge of the Nolichucky; another up the Big Pigeon; and another is slowly building up the Little Tennessee. In addition to these, a number of lumber lines have crept from the Great Valley eastward up into the coves. These must either be abandoned when the timber is removed or must remain as local spurlines, since none of them can possibly cross the mountains, except by constructing tunnels whose length and cost would be prohibitive for the amount of traffic they would probably develop.

Barrier effect.—The effect of these mountains has been and must always be to separate the people on either side. They are a very effective barrier and in the early days lead to isolation and neglect on the part of the North Carolina government, for the people who had settled in what was then its western portion. This condition culminated in the virtual secession of the East Tennessee settlers and the formation by them of the short-lived independent state of Franklin. Today while the few roads and several railroads that cross the region permit a certain amount of communication, it is still true that the main line of travel and of trade is not east and west across these mountains, but is northeast and southwest in a direction parallel to them. The Southern Railway, that formerly ran its best trains from Knoxville east to Washington by way of Asheville, now runs them north by Bristol, even though it has to use the tracks of another railway system from Bristol to Lynchburg in order to utilize this better route.

These mountains exert a very definite and positive influence upon the few settlers who are living among them. Those in the more remote coves are isolated, enjoy few opportunities for schools and churches, mingle but little with the rest of the world, and in general have a greatly narrowed horizon. Under such circumstances old social customs and forms of speech, as well as old political and religious beliefs, are preserved long fter they have passed away in more progressive communities. Indeed,

Digitized by Google

the entire social and economic setting of these mountaineers is peculiar, and presents certain problems that our sociological workers are now grappling with. It is by no means certain, however, that these people as a class deserve the rather sharp criticism that has sometimes been heaped upon them. They have very much in their lives and characters that is commendable, and for the most merely need certain conditions bettered rather than to have their entire plan of existence overturned. Conditions well suited to other thickly settled communities might not be at all suitable among the isolated farmers hidden away in remote mountain coves.

Resources.—In a few places in these mountains there are deposits of iron, copper, slate or other materials of economic value, and on the surface there grow in most places, magnificent forests of hardwood trees. The soil in many places is too steep to cultivate without serious erosion. There are, however, mountain benches, many coves, and small stream valleys that may be cultivated, and the forested lands may be grazed. Mining, lumbering, and some special forms of agriculture, such as grazing and fruit raising, offer the most promise for the future of this region. The people will remain a sturdy stock.

GREAT VALLEY OF EAST TENNESSEE.

Features.—This is a broad belt 30 to 60 miles wide, that crosses the eastern part of the State from Alabama to Virginia, and consists of numerous long, narrow valleys, separated by narrow, parallel mountain ridges that trend northeast and southwest, in harmony with the general Appalachian structure. The valleys are rolling surfaces, formed by the solution of the limestone that underlies them and not flat, alluvial ones due to flood-plain building by streams, though each valley usually has a stream of some size with a narrow flood plain as a portion of it. The ridges are usually narrow, steep-sided, and for most part run in straight lines. They are formed generally by the upturned edges of the more resistant rocks of the region, many of which are cherty limestones. In some places the ridges consist of shales. In this case they are usually more rounded and less distinctly linear, even though they may be steeper, than when composed largely of chert. These ridges vary in length from a few to many miles, and their ends often overlap each other in such fashion that in traveling across the Great Valley, it is necessary to make many detours around their ends. Travel northeast and southwest parallel to the ridges is direct and easy. As a result the main lines of communication whether by highway or railway, are those paralleling the topography. Railways that cross the Great Valley, such as the Southern from Knoxville to Clin-

Digitized by Google

ton, or the Louisville and Nashville from Knoxville to Dossett, either make extensive detours in threading their way through the gaps of successive ridges, or resort to long and expensive tunnels where they attempt to go direct.

FIG. 2. View from the east side of Missionary Ridge. From one mile south of the Southern Railway tunnel, looking north.

Early settlement.—The first settlers in the Great Valley entered it from Virginia and settled along the main streams, such as the Watauga, the Holston and the Clinch, possibly because the river flood plains were considered more fertile than the uplands. Fish and game may have been additional inducements. The early towns in the region were built on the uplands away from the streams where these were too small for navigation, but on the streams where they were large enough to float the flat-bottomed boats then in use. Greeneville and Jonesboro, for example, were founded on interstream areas, while Kingsport, Knoxville and Kingston, not to mention others, were built on rivers where navigation was possible.

In the larger valleys, farms of large size were possible, and in some places slave owning became profitable. In most places, however, the ridge and valley topography was unfavorable to the development of large land holdings and of plantation life, and smaller farms became the rule.

Digitized by Google

Slavery did not obtain the same hold on this region that it did in Middle Tennessee. Sentiment on the subject of slavery was greatly divided and abolition societies were founded years before the Civil War. During the war East Tennessee furnished soldiers to both the Union and the Confederate armies, though Union sentiment was predominant. The political beliefs of the region are also a consequence of the same conditions. Most parts of the region are today strongly Republican. Had the surface of East Tennessee been such as to make slavery universally profitable, its history before, during and since the Civil War would have been far different from what it has been.

Types of civilization.—Agriculturally, the valley portions are much more desirable as a rule than the hill portions, and through the principle of the survival of the fittest there has come about a slow differentiation among the people as a result of which the more thrifty and progressive occupy the fertile limestone valleys, and the less energetic have been pushed into the poorer lands of the shale hills and chert ridges. This differentiation once established tends to perpetuate itself, and we find in some places the contrast between the peoples in the valleys and back in the hills very sharply drawn and strongly marked. Needless to say this condition of affairs brings with it certain problems of a social and economic nature.

The wealth and variety of the mineral resources that have been made accessible by the upturning of the rocks of the region, together with other natural advantages, such as the proximity of coal, forest materials and water power, make possible the development of a greatly diversified urban industrial life.

This valley region, cut off from free communication both east and west, has its natural outlet northeastward into Virginia and southward and southwestward into Georgia and Alabama, and commercial and social ties and interchange of people and ideas must always be chiefly in these directions.

CUMBERLAND PLATEAU.

Features.—This division forms a belt 30 to 50 miles wide that extends entirely across the State from Kentucky to Alabama. Its surface has an average elevation for most of the area of about 2,000 feet above sea level, though its culminating points rise to more than 3,500 feet. Its eastern edge is well defined, but its western edge has been made very irregular by the headwater erosion of the streams that rise on its western margin. The general surface of about five-sixths of the plateau is a gently rolling

Digitized by Google

one underlaid, for the most part, by a massive sandstone, but here and there the surface is formed of shales that are in places interbedded with the sandstones. That portion of the surface, however, which lies east of the Cincinnati Southern Railway is not properly a plateau, but is a complex maze of sharp-topped ridges and deep-cut, narrow stream valleys, formed on flat-lying shales and sandstones, by vigorous stream erosion.

FIG. 3. Cumberland Plateau, in Cumberland County.

The larger streams of most of the plateau are sharply cut beneath the general surface and many of them flow in narrow gorges 300 to 500 feet in depth, the valley walls in many places being made of precipitious cliffs that may be in extreme cases 100 to 200 feet in height. This is particularly true of the northern portion of the plateau west of the Cincinnati Southern Railway in Pickett and Fentress counties, and is true in a somewhat less degree of many other parts of the plateau as well. Further, the southern half of the plateau is deeply cleft longitudinally by a long, narrow, straight valley, occupied by the Sequatchie River. The middle portion of the plateau in the vicinity of Crab Orchard, Crossville, and Monterey, is less dissected by stream gorges than elsewhere.

Barrier effect.—The eastern margin known in the southern part as Walden Ridge, and in the northern part as Cumberland Mountain, is itself a steep-walled barrier that is broken by but few gaps that permit easy ac-

Digitized by Google

cess to the plateau surface beyond. In addition to this, the plateau as a whole must be considered as a broad barrier, separating Middle and East Tennessee. The northern half of it, as has been said, is a maze of sharp-topped ridges and deep, narrow valleys in its eastern part, while its western part, although the general surface is almost flat, is broken by many deep, narrow stream gorges, so that it is not possible in this section to establish easy means of communication across the plateau. The southern portion as far north as the head of Sequatchie Valley, is also difficult to cross, because of this valley. There is left, consequently, only a relatively narrow middle belt across which communication east and west may be established with any facility whatever.

In the early settlement of the State, the first immigrants to Middle Tennessee passed around the plateau to the north, through Cumberland Gap, and thence followed down the Cumberland River to the Nashville region, or embarked on the Tennessee River in flat-bottomed boats and passed around and through it to the south through northern Alabama and across West Tennessee into the Ohio, and up the Cumberland to Nashville. For some years after Middle Tennessee had become a permanent settlement, there was no road across the Cumberland Plateau. That region was owned and inhabited by roving Indians and was full of perils for the traveler. A military road was first opened across it in 1787, and in 1799 another one was opened along a somewhat better route some 10 to 20 miles south of the first one and roughly parallel to it. This latter road passed through the gap where Rockwood now stands and by where Crab Orchard, Crossville and Monterey now are. For some years after these roads were opened it was customary for travelers to wait at the eastern side of the plateau until a considerable number had gathered, when they were escorted across it by a detail of soldiers, so great were the dangers of the journey. Even today one may often travel in certain sections of the plateau five or ten miles without seeing a clearing or a habitation, and in eastern Fentress and Pickett counties there are many square miles without an inhabitant. The country is so rough and wild that it has always been popularly known as "the wilderness". It is perhaps more nearly a wilderness in the true sense of the word than any equaled sized area east of the Mississippi River today.

Railways.—For years the only railway connection between Middle and East Tennessee was through the break in the plateau on the southern margin of the State where the Tennessee River cuts its way westward and southwestward across it. This railway, the Nashville, Chattanooga and St. Louis, long enjoyed a monopoly of transportation between these other-

Digitized by Google

wise separated sections, and was largely instrumental in the development of the city of Chattanooga at the eastern terminus of this crossing. Efforts were made for years to establish railway communication across the plateau proper, but these were successful only in very recent years, when the Tennessee Central was finally completed across the middle section of the plateau through Monterey, Crossville and Crab Orchard to Rockwood, following closely the route of the better of the two roads of pioneer days, and utilizing almost the only practicable route for a trans-plateau railway. Notwithstanding this, it is greatly handicapped by heavy grades on the east and west margins of the plateau.

Resources.—The soils of the plateau are as a rule thin and sandy, and yield, under the ordinary careless methods of cultivation, only scanty crops. They are, however, under skillful management, capable of much improvement. Grazing and fruit growing are among the most promising agricultural pursuits, but the region can not attain its best development until radical improvements are made in the methods of agriculture usually practiced, and these improvements are matters of slow introduction. Over most if not quite all of the plateau slavery was unknown, and the inhabitants cared nothing for it and had little or no interest in the problems that grew out of it. During the Civil War, they either remained at home, or, if they entered the contest, they divided along lines of cleavage made possible by the existence of old family or neighborhood grudges and feuds, and a good part of the fighting was of a local or guerrilla character between bands of so-called home guards. The passions thus engendered lingered for a time but have since died away, and the feud, as an institution, can hardly be said to exist in the Cumberlands today. Moonshining is prevalent in certain communities, but is by no means universal, and the moonshiner is not usually the desperado that the reporter and novelist usually picture him to be.

Social conditions.—The population in some of the plateau counties is practically at a standstill. Houses are often so widely scattered that the inhabitants are greatly isolated, and suffer from the many effects of such isolation. Such conditions make for monotony in life and prevent development along many lines that are possible only in a more thickly inhabited country. Schools, churches, roads, villages and other features of community life are but poorly developed. Living conditions in many cases are correspondingly primitive.

Present conditions are complicated in part of the region by the fact that much of the land within the past few decades has passed into the

Digitized by Google

hands of large companies that have purchased it for the coal and timber. In some cases these companies permit and even encourage the original inhabitants to remain upon the land, on what practically amounts to a system of free tenantry, since they consider their presence desirable for the protection that they may afford against forest fires and depredations by timber thieves or other trespassers, as well as to furnish a source of labor for the operation of mines, logging camps, and lumber mills. In some other cases, however, the policy of the large landowners has been to encourage the original inhabitants to remove from the tracts and in such sections their former homes have gone to decay, their small mountain fields are growing up in forests again, and in a few decades almost all signs of civilization will have disappeared.

Needs of the region.—The future of this region offers most promise through the gradual introduction of better methods of agriculture and the encouragement of stock raising, along with the introduction, probably, of thrifty farming classes from the better sections of Europe, if such can be obtained. The further development of the coal and timber will give employment to the residents and will bring other labor into the sections so exploited, yet such labor does not generally add materially to the permanent prosperity of a region. The population around a logging camp or a lumber mill is too often a shifting one, and usually disappears when lumbering operations are over. Mining camps exercise little or no influence upon the general agricultural development and prosperity of the community, since the energies of their inhabitants are concentrated underground in the development of the coal that is being mined.

HIGHLAND PLAIN.

General description.—This physiographic unit is somewhat complex and is difficult to define in simple terms. From the Cumberland Plateau it stretches westward approximately to the Tennessee River, where it crosses the western part of the State. From an elevation of about 1,000 feet on the eastern border the surface of this plain slopes gently westward to an elevation 600 to 800 feet. In Middle Tennessee, in the very heart of the region thus included, the rocks which elsewhere lie horizontal beneath the plain have been slightly uparched into a low dome from which erosion has eaten out an oval basin 60 to 80 miles wide and 150 miles long, with a surface 300 to 400 feet below the general level of the encircling Highland Plain. This plain is in consequence more usually known as the Highland Rim, a term, however, which ignores the true nature of the

Digitized by Google

highland surface as a plain that in many places is well developed and of broad extent, as for instance, about Tullahoma, McMinnville, Clarksville, and Dickson. The edges of the rim surrounding and overlooking the Central Basin are usually intimately dissected into steeply-rounded hills and spurs that form one of the roughest parts of the Highland Plain. Another portion of the plain that is well dissected by streams is the part just east of the Tennessee River in Hardin, Wayne, Perry and adjoining counties. Erosion here has usually been not more than 100 or 200 feet in depth, and even the worst eroded part of the region presents no such obstacles to travel and free communication as are presented by the deeply dissected portions of the Cumberland Plateau.

FIG. 4. View from Sunset Rock, Monteagle, looking north. Shows spurs from the Cumberland Plateau, jutting out on the Highland Plain.

Influence of geology on topography and soil.—The general surface of the Highland Plain is somewhat complex in its geology, and this has resulted in certain differences in topography and soil that have had a more marked influence in the development of the plain than any other. A part of the surface is underlaid by the St. Louis limestone and has the rolling topography usually characteristic of limestone solution surfaces. It also has the good soils that are usually an additional characteristic of such regions. A second part of the plain has a siliceous shale as its underly-

Digitized by Google

ing rock and has in consequence a thin, siliceous, silty soil whose surface is more nearly flat than the limestone area, and is in some places poorly drained and infertile. A third portion of the plain has a surface composed of flat-lying beds of sandstone that have resisted erosion more than the surrounding rocks, and in consequence stand above these rocks as flat-topped ridges or mesa-like areas that usually have a poor soil and are generally uncleared and uninhabited. Such areas as these form the ridges between McMinnville and Livingston. In other parts of the Highland Plain they either do not occur or are of little importance.

Settlement.—The settlement and subsequent development of the Highland Plain have been largely controlled by these soil differences. In areas of good limestone soils it has been but natural that the inhabitants should become more prosperous and progressive than those in areas of poorer shales and sandstones. In fact many areas of these poorer soils have an exceedingly scant population even today, while the more fertile limestone areas are thickly settled and prosperous communities. The growth of the towns of the region has depended, like the general growth of the population, upon the fertility of the soil of their immediately vicinity and their relative size and prosperity is at once a result and an index of the general fertility of the particular section in which they are each situated, since their prosperity depends almost entirely upon the agricultural resources of the surrounding country.

The different soil conditions largely determined the past economic and political history of the section, governed the development of slavery in it and in consequence determined the allegeance of the inhabitants during the Civil War, some to the Confederate, and some to the Federal cause. In politics the region is predominantly Democratic.

Future of the area.—The future development of this region must show, as its past has shown, differences in development that are traceable primarily to differences in soil fertility. Some sections will always be more prosperous than others. Improved methods of agriculture have, however, shown within recent years, that it is possible to handle the soils of the poorer areas in such manner as to produce excellent crops. The general adoption of these improved methods must lead to increasing prosperity in such areas, and these will tend to minimize the social and industrial differences that now exist between the more and the less fertile sections of the Highland Plain. The future of the region is almost entirely agricultural since there are, generally speaking, no mineral deposits of great importance save in certain sections of the western portion where, locally,

Digitized by Google

iron ores are abundant. Much of the timber of the region has been cut and the tendency is, as everywhere, toward its further destruction. This section is capable of supporting a very much larger population than it now has, under conditions that will vary from medium to good, and there is no inherent reason why it should not as a whole become quite a prosperous section of the State.

CENTRAL PLAIN.

Origin.—This division of the State forms a basin that has been produced by the erosion and unroofing of the gentle dome mentioned in the description of the Highland Plain. It is 50 to 60 miles in width and about 100 miles in length, with its longer axis extending somewhat northeast and southwest. Murfreesboro is a few miles southeast of the center of the basin and Nashville is situated near its northwestern margin. The general surface of the plain is some 300 to 400 feet below that of the surrounding Highland Plain.

Drainage.—Cumberland River flows into the basin or plain from the northeast, and after receiving numerous tributaries within the basin leaves it by a relatively narrow groove cut in the northwestern part of the surrounding Highland Plain. Harpeth River rises in the Central Basin and flows northwestward out of the basin in a similar valley cut in the Highland Plain. Duck and Elk rivers drain the southern part of the basin and likewise cut through the encircling highland. It is evident that all of these streams were in existence before the basin was formed and that they cut their way downward through the rocks of the encircling rim as the central dome was unroofed by erosion and the basin slowly developed. In no other way can one explain why rivers flow from a lower land across a higher one. It is well known to geologists that the Central Basin was never a lake as some have supposed, and the streams that leave it could never have been outlets by which the supposed lake was drained. It would have been exceedingly improbable that a lake would ever have four outlets and much more improbable that each would have cut down at so even a rate as to have all survived the draining of the lake.

Surface.—The general surface of the Central Plain is a gently rolling one produced by stream erosion and solution on limestones, whose doming is so gentle that they are almost flat-lying. The soils of the region are the insoluble residue left by the solution of the limestone. Where this solution has been more rapid the soils form a thick surface mantle, but where the limestones are more cherty and hence less soluble, the soils are

Digitized by Google

thin and the surface is glady. A portion of the limestones contain a considerable percentage of phosphatic matter, and their solution has left a soil unusually rich in the form of plant food. The soils of this phosphatic type attain their best development in the region of Columbia and Mount Pleasant, and this is the secret of the high, natural fertility of that and some of the other portions of the Central Basin.

The bounding margin of the Central Plain or Basin is not a simple and smooth slope, but on the contrary is usually very irregular, since it has been formed by the headwater erosion of streams that are eating into the surrounding Highland Plain and enlarging the area of the Central Basin at the expense of this upper plain. The result has been an irregular,

FIG. 5. Central Plain, with Highland Rim in background.

crenulated margin such as may be seen at almost any point around the basin.

Conditions almost everywhere in the Central Plain have been good for settlement and development. It may be looked upon indeed as a region of physiographic liberty where man might settle practically anywhere and develop according to his own inclination. There has been comparatively little in the way of natural restraint or compulsion to determine and direct man's activities in the development of the Central Plain. A good farm or a village might be established almost anywhere. Perhaps the nearest approach to guidance in the region has come from the existence at a few places of geological faults or breaks in the rocks up along which salt waters have for ages found their way to the surface, producing salt springs or licks. These springs became the meeting place for the wild

Digitized by Google

animals of the region in their search for salt, and in consequence attracted the Indians and later white hunters, fur traders, and finally the pioneer settlers. Nashville, for instance, owes its location chiefly to the existence of a large salt lick where the French, as early as 1713, established a trading post. The presence of bluffs along the river was probably an additional, though subordinate, factor in determining its location.

Development.—Most settlements in the region were largely the result of chance or individual preference. Perhaps the existence of a large spring was more nearly a determining factor than any one thing; while a

FIG 6. Marginal view of the Highland Rim and the Central Plain.

chance mill or some small stream or a crossroads store with the blacksmith or cobbler's shop that often accompanied it, may have formed a neuclus for the development of a town. Most towns of the Central Plain show scarcely more important determining factors for their location than these. The growth of the towns of the region has depended for the most part on the fertility of the immediately surrounding country, and upon the transportation facilities and proximity of neighboring towns.

The development of highways presented no difficulty on such a rolling to nearly level surface and roads were built wherever desired. The same thing has been true of railways. They have been constructed without difficulty across any part of the Central Plain. They have, however, met with considerable difficulty when attempting to leave this plain, since it

Digitized by Google

has been necessary for them to climb some 300 or 400 feet in order to reach the level of the surrounding Highland Plain. The Louisville line of the Louisville and Nashville Railroad, for example, has heavy grades where climbing out of the basin near South Tunnel. The Evansville line of the same road for years operated a three or four per cent. grade between Baker and Ridgetop at great expense for maintenance, and with constant danger of having run-away trains. It has recently rebuilt a number of miles of track there and constructed a tunnel almost a mile long at an expenditure of several millions of dollars, in order to overcome the physical obstacles presented by this rim. The Tennessee Central Railroad leaves the basin to the west by following the valley of Cumberland River, and so avoids heavy grades. To the east of Nashville it climbs out of the basin by a long heavy grade. The Nashville, Chattanooga and St. Louis Railway has expended large sums of money in decreasing the heavy grade on the western edge of the basin between Pegram and White Bluff, and its main line to Chattanooga has a similar steep grade just north of Tullahoma.

The development of civilization on the Central Plain has probably been more homogeneous than elsewhere in the State. Conditions there on the average have been better than elsewhere, and so there was in early days a rather more rapid settlement of the region and development of culture and wealth. Land holdings were often large, and farming on an extensive scale by slave labor was usually profitable. The sympathies of the people were in consequence strongly southern, and in the Civil War they entered the Confederate Army. Since then the region has been Democratic in political faith and conditions are such as to warrant the prediction that it will remain so.

So far as physical conditions go there is no adequate reason for any marked difference in political faith or social or industrial life in the Central Basin. Practically all interests and pursuits are similar, the soils and products are largely similar, and hence all phases of community life may be expected to be much alike. Such political differences as have marked some sections of the region in the past have been due to the strong personality of some political leader whose influence and personal following have swayed the votes of his county or section at certain times in some special direction. These differences have usually disappeared soon after the leaders that caused them have ended their political careers.

The future of this region will be one of continued homogeneous development under very favorable natural circumstances. This development

Digitized by Google

will be most largely agricultural and will be pitched on a relatively high plane.

WEST TENNESSEE PLAIN.

General character.—This is a part of the Gulf Coastal Plain which reaches its northern limit in southern Illinois. The eastern edge of this division may for the present purpose be taken as the Tennessee River in its northward course across the western part of the State. The plain slopes gently westward from an elevation of from 500 to 700 feet on its eastern margin to an elevation of 300 or 400 feet, where it overlooks the Mississippi flood plain. Its surface is a gently rolling one that becomes somewhat broken along the main streams. It is distinctly hilly along its eastern margin facing the flood plain of the Tennessee River, and its

FIG. 7. Characteristic view in West Tennessee.

western one overlooking the flood plain of the Mississippi. The streams that drain its surface head near the Tennessee and flow westward into the Mississippi. They have cut their channels down to low grades, flow sluggishly in meandering courses, and have usually developed flood plains from a half to several miles in width. Owing to their low grade, these flood plains are usually swampy, and one of the present day problems of the region is the drainage and reclamation of these swampy lands. The upland soils of the region are either sandy, loamy, or clayey, and the distribution of the soil types is dependent upon the various geological formations of the region. These outcrop in belts whose general course is north and south. The sandy soils may be, according to circumstances, either fertile or infertile. The loams are usually fertile, while the clays are usually poor.

Digitized by Google

Settlement.—The settlement of the country has been confined to the uplands away from the swampy flood plains. Farming on an extensive scale became the rule wherever the soils were good, slavery and cotton became features of the life. The slave owners were of course southern in their sympathies, and have been Democratic subsequently in their political faith. It is of interest, however, in this connection to note that a belt of sandy and clayey soils in parts of Hardin and McNairy counties was not favorable to large land holdings and slave labor. Farms in this section were usually smaller and slave labor was not profitable. During the Civil War the inhabitants largely went to the Federal Army, and are in political faith today largely Republican.

Roads in this region have liberty to go practically anywhere, the only obstacles being the swamps along the larger streams. Railways in like manner may be located wherever desired, and towns have grown up with little or no physical restraint as to their location. Chance, or at least other features than those due to the physiography of the country, have been responsible for their location, and their subsequent development has depended partly on the soils of the vicinity and partly on the development of railway communication.

Along the Mississippi, there is usually a flood plain of some width between the stream and the edge of the upland. At three points, however, the river swings against the upland on the eastern side of its valley and has formed bluffs. Towns known as Fulton, Randolph and Memphis were early founded on these three bluffs. Of these, Memphis soon gained an advantage because of conditions that were largely fortuitous, and as a result of its early vigorous growth has attained an ascendency that has enabled it to completely overshadow the other two.

The future of the West Tennessee region should be that of agricultural prosperity. There is already much good agricultural practice, and with further improvement of conditions in farming, the development of better roads, the drainage of the river swamps, and the further extension of truck and small fruit farming, there should be an excellent basis for permanent community prosperity. There are, however, in the region just enough lands that are naturally poor to give a semblance of excuse for local thriftlessness, and so we may expect for years that backward communities will exist locally in the region.

WESTERN VALLEY OF THE TENNESSEE RIVER.

In its lower course the Tennessee River flows north across the State and has cut a valley usually several miles in width to a depth of 300 to

Digitized by Google

500 feet beneath the upland plain on either side. Much of this valley is above the reach of ordinary floods and it is largely cleared and farmed, though there are parts that are low and swampy.

THE FLOOD PLAIN OF THE MISSISSIPPI.

Except at the three bluffs above mentioned, there is a variable width of flood plain between the western edge of the upland plain of West Tennessee and the Mississippi River. Near the banks of the river, this flood plain is high enough to remain above water in all but the highest floods.

FIG. 8. View of the Mississippi River at Memphis.

Much of this part is cultivated. Farther back from the river the elevation is less and the surface is frequently flooded. It is poorly drained and swampy and is not cleared. With the perfection of the levee system and the drainage of the lower parts, this rich alluvial land should produce immense crops and support a large population.

THE THREE GRAND POLITICAL DIVISIONS OF THE STATE.

The features of the State lend themselves easily to a three-fold division for political purposes that has been long recognized and observed. The

Digitized by Google

division is into East, Middle and West Tennessee. The line separating the East and Middle divisions crosses the Cumberland Plateau so that it is divided somewhat equally between them, while the line separating the middle and western divisions is approximately the lower or northward portion of the Tennessee River. East Tennessee is Republican in politics and is interested in diversified agriculture, mining and manufacturing, while Middle and West Tennessee are Democratic politically and interested primarily in agriculture. The two latter divisions with their common politics and similar, though by no means identical, interests, usually dominate in political matters.

In early days there was a land office and a treasurer for each of these three divisions. The Supreme Court still sits in rotation in East, Middle and West Tennessee. There is a state normal school for each of the three divisions and a state asylum for each division. In the constitution of political boards and committees it is usually specified that equal representation be given to each of these three divisions, so that in many ways the State comprises three separate communities more or less distinct and different from each other, and yet united under one system of government.

GENERAL PREDICTION.

It is always hazardous to play the role of prophet, but a few general conclusions would seem warranted from the facts at hand.

From the diversity of its soils and its surface features and the stimulus of altitude, climate, and the partial obstacles to free communication that obtain in the valley region of East Tennessee, the development of civilization there in the future should produce our highest type of progressive citizenship, marked preëminently by individuality and independence in thought and action, and with more diversity of industrial activity than any other part of the State. Its people should naturally be more nearly radical in their views than in other parts of the State, and might be classed as the future radical progressives of Tennessee.

Middle Tennessee should develop the highest type of conservative cultured citizenship,—a citizenship more inclined to be content with the conditions and institutions as they are and that will take its religion, its politics, and its general outlook on life from a conservative instead of progressive or radical standpoint. It will be more nearly the holding ground for older ideas and its people may be denominated the future conservatives of the State.

West Tennessee is more nearly like Middle Tennessee than East Tennessee in the physical conditions that must influence and largely determine

Digitized by Google

its future development. Consequently the type of civilization and citizenship to be developed there in the future should take much the same trend that will characterize Middle Tennessee.

Of the cities it is even more difficult to hazard a prediction. Knoxville has the natural resources, both mineral and others, that should make it a great manufacturing city. It is, however, hemmed in by the Appalachian Mountains on the east and the Cumberland Plateau on the west so that its industrial and commercial communities must always be confined to the outlet northeast and southwest along the Great Valley.

Chattanooga has slightly greater advantages in its wealth of natural resources, particularly iron and coal, than has Knoxville, and while it has the same commercial outlets northeast and southwest along the Great Valley that Knoxville has, it has, in addition, a westward outlet toward Middle Tennessee, and an eastern and southeastern one through northwestern Georgia, around the southern end of the Appalachians, and it would, in consequence, be picked as the future first city in the Great Valley of East Tennessee.

Nashville, in its future growth, should normally partake of the characteristics of the inhabitants of Middle Tennessee, and may be expected to build along conservative lines, with nothing radical in its industrial or commercial life. This development should, moreover, show a positive influence from the educational interests that are centered in the city.

Memphis, from its location on the great river, its railways and the large tributary territory, is destined to be the great commercial center and probably the wealthiest city of the State, just as Knoxville and Chattanooga will be the greatest manufacturing centers.

Digitized by Google

Care and Protection of Forests

By R. S. Maddox.

Need of forests.—We can not overestimate the value of forests. They are a necessity. Without them human beings could scarcely exist, because they play such a part in the conservation of our water supply, and because they are producers of lumber and other forms of wood so indispensable to man; in fact, forests may be said to make conditions on earth possible for man's existence. They are cooler in summer, and warmer in winter than bare land, and thus help to make climate more endurable. They break the force and violence of wind. They help to hold the rainfall for a gradual seepage into the ground from which it reappears to feed our springs and streams. They are a source of supply from which man has always been drawing, a reserve which he has too long left uncared for, a gift which he has too often considered a spoil for plunder. Much damage has resulted from their destruction or abuse. The cleared land just as easily and freely pours the rainfall down the slopes, as the well protected, wooded area prevents it from running off. Land unfit for cultivation, and which should have been kept covered with trees, is a great contributor of soil to the floods of water that rush over it. It is like a vine with its tendrils cut off, having nothing with which to hold. If it has been cut over, with the brush and trash left on the area, these furnish excellent fuel for the forest fire that runs through it to burn off everything.

Care of the forests.—The importance of caring for and protecting the forests and forest land of Tennessee can not be emphasized too strongly. They are disappearing from lack of proper use and protection. Too great quantities of timber can not be cut continuously without exhausting the supply, and much land that should be left for timber production is cleared for cultivation. Not enough care is given to land already tilled. When one area becomes washed and worn, another piece of woodland is cleared to fill its place. A big per cent of the land used for farming will last only a few years under the present system of cultivation, and it seems that our woodlands are doomed to supply a never-satisfied want for more land to take the place of that which is being discarded as unfit for further farm use. Forestry and farming come close together and every farmer of the State should be a practical forester.

Digitized by Google

It takes a long period to grow forests of big trees, but they may be cut down and used, or wasted, in a comparatively short time. It is likely that the future crops of trees will be harvested before they reach near the age of the old stands of virgin timber. However, through some method of regulating the cut, or for the express purpose of securing certain kinds of clear lumber, the trees may be left to grow to a large size. But whether trees are cut in the future at an earlier age or not, it is important always to have plenty of them in the right places and well cared for.

It takes only a few months to grow and harvest ordinary farm products, such as cotton, corn and wheat. In fact the whole work of producing each crop is of short duration. The farmer plows his land, plants, cultivates, harvests and markets his crop in the same year. His labor produces a quick return. His sheep, cattle, horses and hogs are ready for market in a comparatively short time, say from one to five years. But in contrast to these short time productions of the farm, is timber, no less a farm product because of the comparatively long time it takes to mature. Nearly every landowner in the State has his wood lot or "woods" as it is generally called. He secures from his crop of trees such materials of wood as are necessary for his comfort and convenience. If he cuts off a portion of his wood lot for fence rails, posts, fire-wood or lumber, he may see a fine crop of young trees come back to take the place of the old ones. Likely he will not live to see them grow to a stand of large mature timber.

The farmers of the State own a very large amount of the woodlands of Tennessee, and practically all the rest belong to other private individuals, companies and corporations. From them must come a great help in taking care of, protecting and perpetuating the forests and timber supply. One may say he has enough to last him his lifetime, which is doubtless true. But that is not the question; after him there are others coming who will need and can not do without wood, not to mention any of the other benefits of the forest.

The timber of the State was once very abundant, and the population relatively small. Nature has furnished a supply ready at hand which had required no effort from the settler to produce. He simply took it over as a natural right and used it pretty much as he pleased in his limited way. Markets were hard to reach, railroads few or none, the waterways little used, and therefore the amount of lumber reaching the markets was small. But now since the population has increased, and railroads and water transportation have so developed, the heavy demand for lumber has rapidly drained our forests until we are under obligations to take care of what remains of them. The people need more and better timber and they can

Digitized by Google

not afford to draw recklessly upon the present stand. The careless, wasteful method of handling it must become a thing of the past in order to supply the constant demand and check the rapidly growing scarcity of lumber. It will take intelligent thought followed by intelligent action, to make the forests better, and keep them from undergoing further destruction and deterioration.

Everyone, especially the consumer, knows the price of lumber is high and going higher. Those who own timber should take care of it, just as any other property. This does not mean they ought to let it stand and go to waste. Timber should be used, but used properly. It should be utilized in an economic way. Also a new growth should be secured and freed as far as possible from forest fires, especially dangerous to newly cut-over lands.

No remaining woodland should be cleared without carefully considering whether it is worth more for farm land than for timber. Certainly some should never be cleared, but kept for tree growth; for if cleared and put under cultivation, they would soon wash away, unprotected by the forest cover. Nearly everyone can bring to mind land of this character, which has been cultivated only a few years, and which has become worn out, full of gullies, and shows many "hang-rocks" on the surface. The washing away of the soil has left rock outcroppings, which would make the land difficult if not impossible to cultivate, even though it had not become poor.

It necessarily takes a great deal of timber to supply the stove and fireplace. But a big saving of the better class of timber could be made and still have them well furnished. Many trees of the better class find their way to the "wood-pile" because they are easier to "work up" than the knotty trees. The good trees should be allowed to grow and mature for a more profitable use. There is usually enough dead and down timber, and trees of poor quality and inferior species to supply fire-wood, and besides, the room they take up is frequently needed to give sufficient space for the more rapid growth of the better species. It may take more time to prepare the poorer than the better class of trees for wood, but a gain will be made in saving the latter for lumber.

The farmer would scarcely think of attempting to grow his cotton and corn crops without a certain amount of thinning. The same principle applies to trees. The scrubby and inferior ones can be cut over for use and the stand left improved. Even if thinning is not necessary to give room for growth, the space occupied by them, if they are removed, would have a chance to be taken up by the better class of trees left standing. A

Digitized by Google

man can exercise as much judgment and show as much business ability in managing his timber as in any other phase of his work.

Fire damage to trees.—One of the chief ways of protecting woodlands is to keep fires out of them. Every other kind of property subject to fire damage has more fire protection than timber. When buildings catch on fire the alarm spreads rapidly and aid comes from all directions. In the country, town, or city the cry for help from fire has a ready response, and every effort is made to save life and property, since there exists a strong sentiment against loss by fire from buildings and their contents.

On the other hand, the boiling smoke of a forest fire rolls up from the woods, or mountain side; no alarm is given by shout nor bell; no crowd

FIG. 1. Showing a stand of young oaks, 15-20 years old, near Tracy City, and the forest conditions where fires have not occurred for several years.

nor firemen rush to the scene. Men and women go on about their business. Some look at it indifferently, others gaze with admiration at the size and brilliancy of the flames, or the enormous clouds of smoke rolling heavily upward. They may not feel that damage is being done, because they do not realize the injury to forests from fire. They may not care, but yet they are gazing upon a source of destruction from which the people of the State suffer an immense loss every year. The injury is of such a nature that it does not come as close to us as that from loss of other property. For example, we live in our houses built especially for our com-

Digitized by Google

fort, and at an expense of money and hard work; our farm lands yield us provisions, and products for quick money, and any injury to these possessions affects us at once. But the benefits from our forests are not so direct, and therefore if they burn, the loss is not felt so quickly. A stand of young timber may burn over and no marked damage show at a glance; a majority of the trees may put out leaves the following spring, and the area appear full of life. The same woodland burns over every few years and still shows, especially at a distance, a good cover of leafy tree tops in the summer, yet this stand of young trees has suffered and will continue to suffer as long as fires run through them. Portions of bark on the butts have been scorched and have died; the dead places give rise to disease, rot and hollow butts which stay with the stand throughout its lifetime, and render a big per cent of the timber unfit for lumber. A great many trees break off at the ground because the stump was weakened first by fire and then was attacked by insects, fungi, or disease of some sort. Such is the case everywhere, and people have no doubt become so accustomed to it that they take it as a matter of course without stopping to lay the cause to forest fires that began when the trees were very small, and have recurred at irregular periods.

The saw-mill operator is well acquainted with these defects whether or not he thinks of the cause, and when he buys standing timber he is sure to make a certain per cent reduction in his estimate, because of them. The farmer often wonders why so many of his trees have hollow butts. One of the chief reasons is their having been burnt repeatedly from the time they were small. The burnt places on the stumps decayed, perhaps became infected with insects, and when the next fires came along the dead wood burned a little more, helping to kill the sap next to it, thus enlarging the size of the burn. It can be easily seen how this process, repeated time and again, results in a number of diseased and hollow butts by the time the area has on it a stand of large trees.

Our future timber supply must come from the sprouts and seedlings of our woodlands. They stand for the same thing among trees that babies and children do among men. A large amount of the timber that could be produced is lost on account of damage from fire. The very part of the tree that should give the clearest, strongest and best lumber has to be left in the woods. The total of such butt logs makes a large amount, and this loss places upon the people an extra tax in the form of a higher price of lumber, to say nothing of the inferior grades. No tree can grow its fastest if constantly burned and diseased; no land can produce its best if it constantly has the decayed vegetation removed. In order to keep our

Digitized by Google

woodlands in condition for their best and most rapid production of timber, they must have protection from fire.

Fire damage to run-off.—Besides the loss in tree production, another phase of the serious damage resulting from forest fires is the rapid run-off of the rainfall and the hastened evaporation resulting from the constant burning of the leaf litter. A heavy downpour is followed by a rapid rise in the streams, often sufficient to carry them out of banks, and to sweep away fences, logs, crops, etc. This is looked upon as a natural event and unavoidable; water falls and it must have some way of escape. But it need not have a free and unobstructed right of way overland to wash and pillage. A part of the rainfall is taken up in wetting vegetation before it reaches the ground, a part evaporates, but as much of the remainder as possible should find a way underground, and so far as our forests are concerned this could be accomplished by a little precaution.

FIG. 2. A sample of the mountains near South Pittsburg, where forest fires have kept the ground cover burned off. Erosion and injury to trees are very noticeable in such areas.

The forests, by the annual shedding of their leaves, furnish a ground covering that absorbs and holds a large amount of water until it can soak into the earth. This litter is a natural ground protector and one that is provided by the trees throwing off what they no longer need. It should be kept and preserved; in other words, it should not be allowed to catch on fire.

Digitized by Google

In the mountains around Sewanee, Monteagle, Tracy City and South Pittsburg, I have recently seen streams swollen out of all proportion, because the repeated forest fires have prevented the accumulation of a thorough ground cover. There can be no question that the high waters of the streams of Tennessee, during the wet season of the year and the low water during the dry season, are partly due to the destruction by fire of the leaf litter on the forested lands.

Fire damage to birds and game.—There is a great deal said about the general scarcity of birds and game. Not only are certain kinds of song birds rare, but also game birds, such as quail, and turkey, becoming scarce. Deer are rare and apparently becoming fewer in numbers, and likewise other wild animals that in many parts of the State used to afford the hunter a certain amount of sport and profit. While this may be largely due to other causes, yet forest fires can certainly be held responsible for taking a part in it. There are certain restrictions by law that place a protective influence around game and birds. Some are protected all the time, others in certain seasons of the year, and during the open season the number lawful to bag in a day is limited. But forest fires are freely permitted to destroy and drive out all they can. They may happen any time of the year when the leaves become dry enough to burn. Certain song birds as well as game birds live in the woods, build their nests in the leaves, grass, shrubs and bushes, and rear their young there. If the woods burn before the nests are built, the ground litter is destroyed in many instances so that it does not furnish proper nesting places. The birds are thus forced to other quarters. The nests are exposed to fire danger from the time they are built until abandoned by the young birds. If the woods burn after the nests contain eggs or young birds, there is no question as to what becomes of them. This is true, both of song birds that nest on or near the ground, and of game birds, such as quail and turkey mentioned above.

Furthermore, forest fires destroy the feed for birds. The flames consume seed and other material that support bird life, and make living hard or impossible, for them. Their lodging places, and the small undergrowth that protects them, are injured, thus destroying the natural conditions under which they thrive.

The deer is a timid animal and wishes seclusion. When forest fires constantly sweep through the haunts of these animals, they are greatly disturbed and driven out for at least a time. It is said that hunters often start forest fires to rout the deer, and then shoot them when attempting to escape.

Digitized by Google

Although these birds and animals receive recognition for protection by law, from hunters, yet their breeding places and lives are constantly endangered and often destroyed through the ever recurring and little heeded forest fires.

Fire damage to grazing.—For many years the mountains in the West have been used for stock ranges. Although the vegetation is comparatively scant, requiring many acres on the average for each animal, the area is so large that it has supported yearly hundreds of thousands of head. For a long time the stockmen made a practice of burning off the mountains with the idea of improving the grazing. But when those lands were set apart as national forest reserves, and put under the administration of the federal government, one part of the work was to put an end to forest fires. As is well known, it is often very difficult to get an old practice stopped, especially if the ones who practice it thoroughly believe in it. So when these grazing lands came under the management of the federal government, and permits were issued to the stockmen to graze their animals thereon, they still believed in the theory of burning as helpful to grazing. But through the government's patient and careful work of range protection from fires, the stockmen began to see that their grazing lands were better if fires were kept out; that fires were a detriment to the grass and forage. In other words, they were shown that they had been doing the wrong thing by allowing their grazing lands to be overrun by fire.

The mountain lands of Tennessee afford grazing to numerous herds of cattle every year. They form a sort of public range to stockmen who live close enough to use them for that purpose, and no doubt suffer from many forest fires, started in the belief that they are a benefit to the grazing. The chances are also that many fires are set because they keep down the underbrush so the stockmen can ride through more easily and find their stock with less difficulty. While the men may be temporarily aided personally by this burning, the damage to the woods is considerable. The grazing also is injured, and the fire has the same injurious effect upon the soil, water-flow and trees, as if it had been set for any other purpose. It is reasonable to believe that when grass and weeds are constantly burned off their growth is injured. Woodlands better serve the public with the fallen timber left for wood, and the leaf cover left to help hold rainfall, than when kept burned over; for repeated burning causes the ground to remain bare, increases floods, and also produces defective timber.

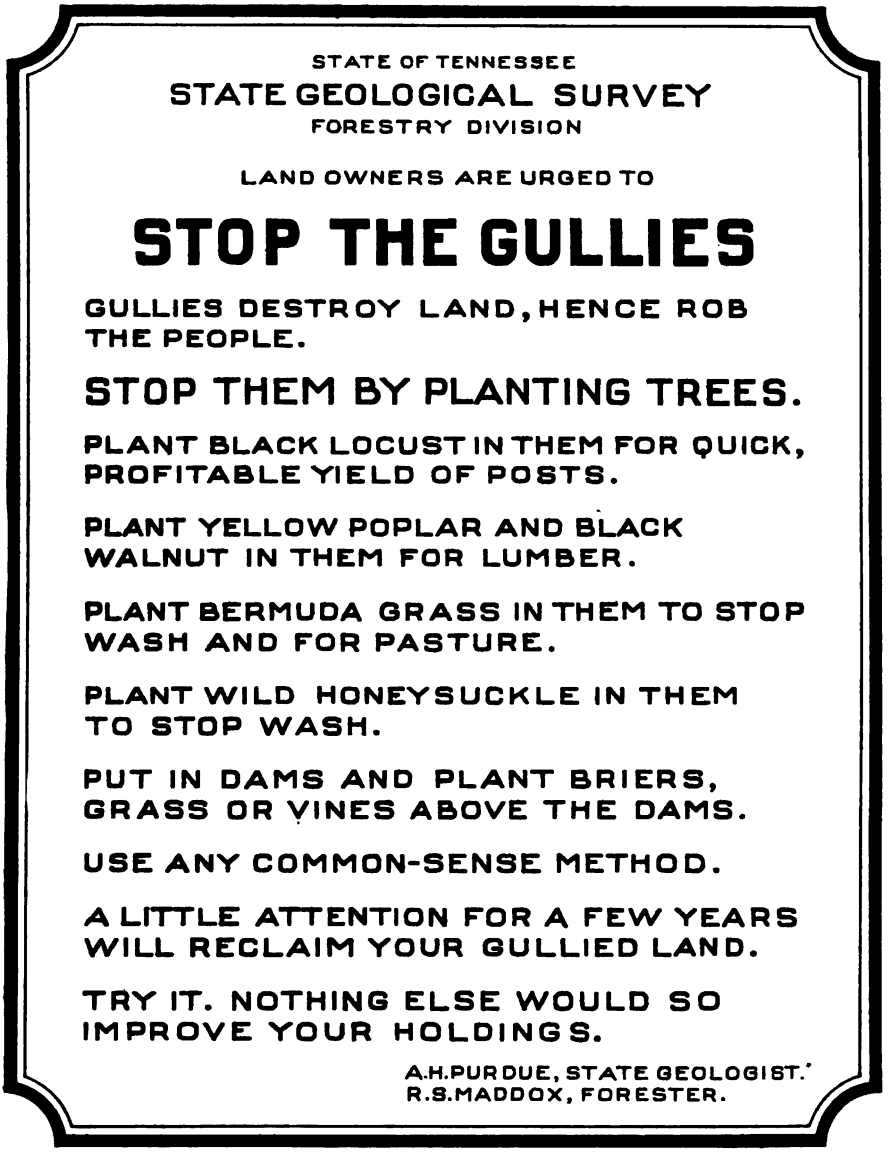
Digitized by Google

Grasses and forage plants can not have the greatest growth unless they have the best soil. Forest fires never help soil. They burn off the leaves and decayed vegetation, the very things that help hold moisture and add fertility to the land. They leave the ground exposed to erosion, and even the ashes that might otherwise have aided plant growth, are easily washed away; they frequently burn or scorch the soil, making it further impoverished for plant growth. Evaporation takes place more rapidly; the soil becomes hard and dry, and plant life can not thrive best under such conditions.

Fire damage to fish.—Everyone knows of the big volumes of water that pass out through our streams during winter and spring; and that streams get very low during the summer and fall. Great quantities of fish can not grow in streams, even those with large beds, if they contain but little water. No one would expect a river to be an excellent fish stream if it went dry or became very low during a part of every year. The smallest amount of water in a stream, at any time of the year may determine the amount of fish that stream can maintain. It may be claimed that a supply of fish will come up stream during high water, and this is no doubt true, but if the streams from which they may come have been likewise low, then their producing capacity has also been diminished and we are forced to admit our fish supply has been lessened all round. And too, if a large number were to come up stream and not go back with the retiring water, when the stream reaches its low mark, it would not be able to support an extra number. Thus some would necessarily die. Low water becomes impure and stagnant, and not best for fish production.

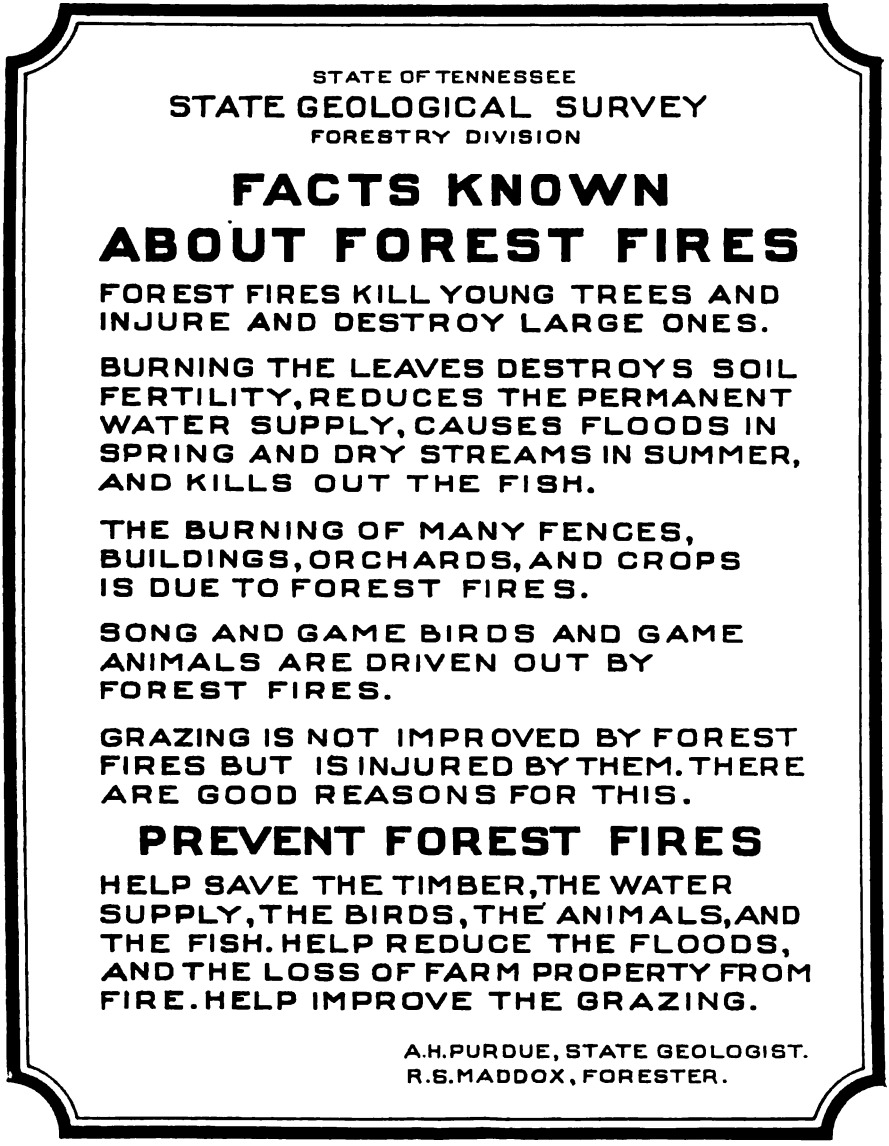
Our streams furnish energy for power plants and other industries, but often is deficient in low water. River freightage is diminished on account of the low water of the rivers in the dry season. And although other causes work to help bring about this lessened amount of water, forest fires must be charged with a very great deal of it.

Digitized by Google


STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
FORESTRY DIVISION
LAND OWNERS ARE URGED TO
STOP THE GULLIES
GULLIES DESTROY LAND, HENCE ROB THE PEOPLE.
STOP THEM BY PLANTING TREES.
PLANT BLACK LOCUST IN THEM FOR QUICK, PROFITABLE YIELD OF POSTS.
PLANT YELLOW POPLAR AND BLACK WALNUT IN THEM FOR LUMBER.
PLANT BERMUDA GRASS IN THEM TO STOP WASH AND FOR PASTURE.
PLANT WILD HONEYSUCKLE IN THEM TO STOP WASH.
PUT IN DAMS AND PLANT BRIERS, GRASS OR VINES ABOVE THE DAMS.
USE ANY COMMON-SENSE METHOD.
A LITTLE ATTENTION FOR A FEW YEARS WILL RECLAIM YOUR GULLIED LAND.
TRY IT. NOTHING ELSE WOULD SO IMPROVE YOUR HOLDINGS.
A.H.PURDUE, STATE GEOLOGIST.
R.S.MADDOX, FORESTER.

The above cut is made from a drawing for a poster that is being prepared by the State Geological Survey, to be put up in those parts of the State where waste from washing is greatest, and where a special effort is being made to have gullied lands reclaimed; but it is applicable wherever land washes. The size of the poster is 10 by 13 inches.

Digitized by Google


STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
FORESTRY DIVISION
FACTS KNOWN
ABOUT FOREST FIRES
FOREST FIRES KILL YOUNG TREES AND INJURE AND DESTROY LARGE ONES.
BURNING THE LEAVES DESTROYS SOIL FERTILITY, REDUCES THE PERMANENT WATER SUPPLY, CAUSES FLOODS IN SPRING AND DRY STREAMS IN SUMMER, AND KILLS OUT THE FISH.
THE BURNING OF MANY FENCES, BUILDINGS, ORCHARDS, AND CROPS IS DUE TO FOREST FIRES.
SONG AND GAME BIRDS AND GAME ANIMALS ARE DRIVEN OUT BY FOREST FIRES.
GRAZING IS NOT IMPROVED BY FOREST FIRES BUT IS INJURED BY THEM. THERE ARE GOOD REASONS FOR THIS.
PREVENT FOREST FIRES
HELP SAVE THE TIMBER, THE WATER SUPPLY, THE BIRDS, THE ANIMALS, AND THE FISH. HELP REDUCE THE FLOODS, AND THE LOSS OF FARM PROPERTY FROM FIRE. HELP IMPROVE THE GRAZING.
A.H. PURDUE, STATE GEOLOGIST.
R.S. MADDOX, FORESTER.

The above cut is made from a drawing for a poster that is being prepared by the State Geological Survey, to be put up in those parts of the State where forest fires are most common; but it is applicable wherever there are forests. The size of the poster is 10 by 13 inches.

Digitized by Google

Two Natural Bridges of the Cumberland Mountains

By Wilbur A. Nelson.

There is probably no portion of Tennessee more beautiful or more interesting to the traveler than the Cumberland Mountains—a rugged belt which stretches nearly north and south across the State, forming a natural barrier between the middle and eastern portions of the State.

Among the many things of interest to the geologist and general observer are two natural bridges, which occur in this region. One, which has been known for years, is about three miles southwest of Sewanee in Franklin County, and is a point of interest to all visitors on the mountain. During the summer of 1913, the writer observed another, located two miles northwest of Dayton, on the eastern escarpment of Walden Ridge. It is so surrounded by trees that unless its location were known one would pass within a hundred yards of it and be ignorant of its existence.

Mode of formation.—The history of the two bridges is similar. The Cumberland Mountains are composed of horizontal beds of alternating sandstones and shales. The bridges occur in the thick sandstone, where the latter forms bluffs along the face of the mountain. A marked vertical jointing, parallel to the face of the escarpment, gives the abundant rainfall opportunity to disintegrate channels 50 to 100 feet back from the escarpment. These channels finally reach, at a lower level, a softer layer of sandstone which generally occurs near the base of the bluff. The water disintegrates the rock very easily and makes its way to the base of the bluff through a joint. This at first a small joint, gradually enlarges until a sufficient size has been reached, when the process is rapidly augmented by the thin bedded sandstone falling down of its own weight, thus completing the formation of the bridge. Eventually the processes that form the bridge destroy it by causing it to collapse and leave only a jagged gate, through which the water flows.

In addition to the water forming a channel along the joint plane of the sandstone, there occurs at each of the two bridges a small spring, which gushes out at the base of the solid sandstone wall, just back of the bridge arch. While the surface water, which flows down through the vertical joints is responsible for separating the arch from the sandstone that caps

Digitized by Google

the mountain, the water from the spring is an important agency in undermining the separated part and forming the bridge arch.

Sewanee natural bridge.—The Sewanee natural bridge is located in Franklin County, three miles northwest of Sewanee, on the west side of Lost Cove. The capstone of the mountain at this point, the Sewanee conglomerate, is the rock in which the bridge occurs. Going down a slight declivity for a hundred yards, one suddenly comes to the upper bluff and

FIG. 1. Sewanee natural bridge. (Photo by Judd.)

sees lying at his feet this wonder of the Cumberland Mountains, while beyond stretches out the narrow, sinuous valley of Lost Cove, flanked by the densely wooded mountains in the distance. In the autumn, when the foliage takes on the colors of the rainbow, this picturesque spot supplies a scene of charming beauty.

The bridge is made of coarse, white, alternating hard and soft sandstone, containing a few small, white, quartz pebbles. The length of the inner span is 27 feet, its height 18 feet, while the thickness of the rock in the center is five feet. At this point it is made of two thin parallel bands of sandstone, the lower one three feet, and upper one two feet thick. The width of the arch at this point is seven feet. The length of the bridge from where it leaves the main bluff to where it joins again, is 130 feet. At the ends of the bridge the width has increased from 7 to 25 feet. The

Digitized by Google

arch is separated from the main bluff by a distance of 25½ feet. In the base of the main bluff, a little to the south of the center of the arch, is a small grotto, 25 feet wide, six and a half feet high, and extending back under the bluff 15 feet. Three small springs flow from the back of this cavity and form a small stream, which flows out under the arch of the bridge.

To this spring is due the erosion of most of the bridge, although it was supplemented by the water running down through the joint plane, which at present forms the inner side of the bridge. At the same time the under side of the bridge was being broken down, and the arch growing larger.

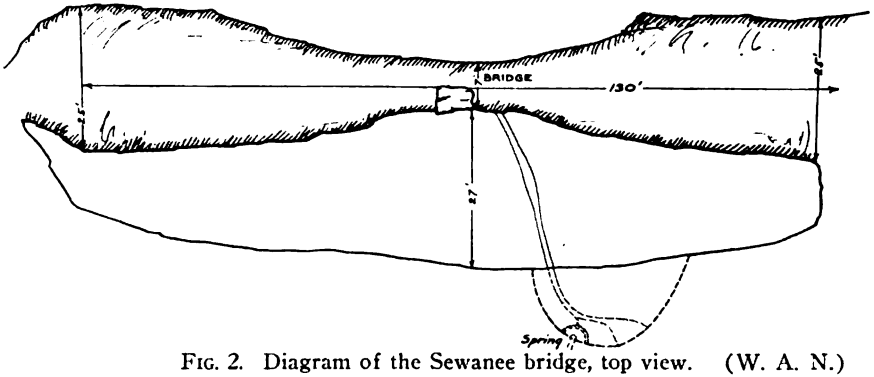


FIG. 2. Diagram of the Sewanee bridge, top view. (W. A. N.)

The rocks forming the top layer of the bridge were being eroded by natural processes, so that one can see from the picture that at least one layer 30 inches thick has been removed. This is evidenced by the small block-like remnant which remains.

Gooch Creek natural bridge.—This bridge, which is on the escarpment of the uppermost bluff, lies on the northwest side of Gooch Creek, three and a half miles north of Dayton, Tennessee. The property belongs to A. W. Walker of that town. The best way to reach it on foot is to follow the railroad to the coke ovens of the Dayton Coal & Iron Company, then turn east and take a logging road over an outlying ridge and down into Gooch Creek ravine, where there is a temporary saw-mill. From this point go about one-fourth of a mile up the creek and then climp up the escarpment of the mountain, 400 feet to the top of Walden Ridge, where the bridge is located. By road one can go up Stewart Gap to the top of the ridge, then walk south a half mile to the bridge.

Digitized by Google

This bridge is so surrounded by trees that it is impossible to get a good view of the arch, but the figures of its dimensions will give some idea of its size.

The greatest inside length of the span is 67½ feet, its height 33 feet, and the thickness of the arch in the center is 18 feet. The width of the arch at this point is 35 feet, while it is 135 feet from end to end. The bridge, which at both ends has a width of 50 feet, is separated from the main bluff by a distance of 19 feet. The Morgan Spring sandstone which composes the bridge is a coarse, yellowish, white sandstone, and does not weather easily. Occasionally one will find a few small, white, quartz

FIG. 3. Gooch Creek natural bridge. (W. A. N.)

pebbles. The rocks are mostly massive and thick bedded, and have a dip of about two degrees toward the mountain, which is to the northwest. The Morgan Springs sandstone is from 100 to 200 feet thick and forms a well defined escarpment along most of the eastern face of Walden Ridge.

In the face of the bluff back of the arch of the bridge is a small basin-like spring about four feet from the foot of the bluff, which forms a natural drinking basin. At the time the locality was visited, which was during a very dry period, the flow was so weak that the overflow was just sufficient to wet the surface of the bluff below the spring. Only during the wet seasons does any water flow through the arch, and this comes

Digitized by Google

primarily from a small surface stream which flows into the north end of the rift behind the bridge, and then under the arch.

This bridge has been formed in identically the same manner as the Sewanee natural bridge, but is not so old. The spring coming from the face of the bluff at this bridge, is weak, while at the Sewanee bridge the spring is the main source of water supply. The undermining of the rock of the arch, which is still thick and massive, is only slight.

Doctor L. C. Glenn reports that another natural bridge exists near the eastern edge of the plateau, in the region just north of La Follette.

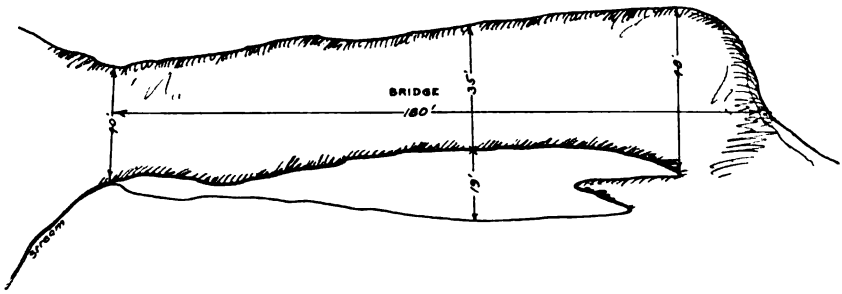


FIG. 4. Diagram of Gooch Creek natural bridge. Top view. (W. A. N.)

Digitized by Google

News Notes

A map of McNairy County is at present being made by the State Geological Survey. It will show all the roads, railroads, towns, residences, schoolhouses, churches, and streams. The scale of the map will be one mile to the inch. Mr. F. W. Farnsworth and Mr. C. R. Watkins, Jr., are employed in the field at this work. Mr. Farnsworth, a member of the United States Geological Survey, but temporarily secured for this work, has been engaged on many maps of this kind. His home is in Dayton, Tennessee. Mr. Watkins, of Nashville, is a civil engineer and has recently been employed in railroad work in Tennessee. He is a graduate of the Virginia Industrial Institute.

The object of such work is to prepare detailed maps of counties of the State which have not previously been surveyed, in order that the geological formations and soils may be represented upon them. Very little of such mapping has ever been done in Tennessee. McNairy County, since it contains material which represents most of the geological formations of West Tennessee, supplies the key to the geological problems of the whole region. It is the intention of this Survey to continue such detailed mapping of the counties of the State as fast as the means at its command will permit. Besides their use for geological and soil mapping, these maps will be of great service to the people of the State, and those outside the State, seeking information about it. Many requests have already been made by the farmers of McNairy County, for copies of the map, when it is published.

To accompany a report on the iron ores of Lewis County, which is now being prepared by Mr. Reese F. Rogers, formerly a member of the State Geological Survey, but now a member of the U. S. Bureau of Soils, a detailed map of that county is being drafted, and will be published soon. The map shows the location of the mines, prospects, and banks of the iron ore deposits. Mr. J. Trousdale Haden, who has recently come to the employ of the State Geological Survey, is doing the drafting of this map as well as that of the coal and marble reports, which are now in preparation by the geologists, Glenn, Nelson and Gordon.

Extensive coal sampling, under the direction of the State Geological Survey, in coöperation with the U. S. Geological Survey, is being done in the Cumberland Plateau coal field. This is in connection with the report

Digitized by Google

on coal by L. C. Glenn and Wilbur A. Nelson. The sampling is being done by Mr. Frank R. Clark, Associate Geologist of the United States Geological Survey. Mr. Clark was selected for this work by the U. S. Geological Survey on account of his large experience in taking coal samples. It has been arranged for the analyses of the samples to be made at the laboratory of the U. S. Bureau of Mines at Pittsburgh, Pa. The purpose of this is to have the analyses standardized so that they will be accepted and understood in all parts of the world.

Mr. R. S. Maddox, Forester of the Survey, is rapidly winning the coöperation of the farmers in the work of saving the washed lands of West Tennessee, by methods which are productive to the farmers themselves. Besides, he is urging the avoidance of forest fires. This work is of widespread public benefit as well as the means of lessening local devastation. Attention is called to the cuts of two posters appearing elsewhere in this issue. One relates to the reclamation of gullied lands, and the other to the prevention of forest fires.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Digitized by Google

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

Digitized by Google

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

Digitized by Google

Vol. III. No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

Vol. III. No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

Vol. III. No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

Vol. V. No. 1—The Hydro-Electric System of Tennessee, by J. A. Switzer.
West Tennessee Gullied Lands and Their Reclamation, by R. S. Maddox.
The White Phosphates of Tennessee, by J. S. Hook.

Digitized by Google

Digitized by Google

TN
24
.T2
A4

Volume V

Number 3

JULY, 1915

JUL 19 19

Tennessee Geol. survey

THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY, AND OCTOBER
BY THE STATE GEOLOGICAL
SURVEY

NASHVILLE, TENNESSEE

A Magazine Devoted to the Description, Conservation, and Development of the Resources of Tennessee

CONTENTS

The Iron Ore Deposits of Lewis County, Tennessee.....Reese F. Rogers
Publications of the Geological Survey of Tennessee.

Entered as second-class matter January 10, 19 13, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

Volume V Number 3

JULY, 1915

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey

NASHVILLE, TENNESSEE

STATE GEOLOGICAL COMMISSION

Gov. TOM C. RYE, *Chairman*

DR. BROWN AYRES, *Secretary*
President, University of Tennessee

H. KNOX BRYSON
Commissioner of Agriculture

DR. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

R. A. SHIFLETT
Chief Mine Inspector

GEOLOGICAL CORPS

A. H. PURDUE
State Geologist

OLAF P. JENKINS
Assistant Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

CONTENTS

The Iron Ore Deposits of Lewis County, Tennessee.....Reese F. Rogers
Publications of the Geological Survey of Tennessee.

Digitized by Google

TN
24
T2
A4

Digitized by Google

The Iron Ore Deposits of Lewis County, Tennessee

By Reese F. Rogers.

INTRODUCTION.

The material for this report was obtained in a detailed field investigation during the winter months of 1912-'13. All the main roads, and most of the secondary roads, were covered. It is believed that nearly all the known occurrences of iron ore in Lewis County have been located and described.

It must not be presumed that Lewis County is the most important iron ore-bearing area of the Highland Rim, for this will remain an open question until detailed field work has been done in the other counties composing it. This the Tennessee Geological Survey plans to do as rapidly as is practicable.

The writer wishes to acknowledge his obligations to companies and individuals for courtesies extended, and for information and assistance freely given throughout the period of field work.

GENERAL DESCRIPTION OF THE AREA.

Location and area.—Lewis County is situated in the southwest portion of the geographic division commonly known as Middle Tennessee, and on the southwest side of the physiographic division known as the Highland Rim. It contains approximately 297 square miles or 190,080 acres, the greater portion of which is covered with second growth timber and classed as unimproved lands. It received its name in honor of Merriwether Lewis, the companion of Clarke in the famous Lewis and Clarke overland expedition to Oregon Territory in the years 1803-6. It may be well to state that near the center of the county, on the line of the old Natchez Trace, while on a journey from the Louisiana Territory, of which he was Governor, Merriwether Lewis, on October 11, 1809, met his death, either by suicide or murder. At this very spot he was buried, and in 1848, the Legislature of Tennessee had a monument erected to the memory of this renowned explorer and patriot.

Surface features and drainage.—Lewis County lies within the deeply dissected plateau known as the Highland Rim, the highest points of which have an average elevation between 900 and 1000 feet above mean sea

Digitized by Google

level. In the Lewis County area the elevation of the plateau will probably average higher than that of the counties surrounding it. A study of the topography of this region clearly shows that the present land surface is the result of the dissection of a level or gently undulating plain, which, if restored, would have an altitude of over 1000 feet.

The surface is composed of high, irregular-shaped ridges with steep slopes to narrow valleys. A mile or more away from the streams the lands become flat and open. There is a belt of such land, averaging about three miles in width, running diagonally across the county from northwest to southeast. The crests of the ridges vary from 900 to over 1000 feet above sea level, and are from 250 to 350 feet above the streams. It is on or near the tops of the ridges that the iron ore occurs.

The plateau-like surface of the county is gashed by many streams. Most of these rise in the county, and flow from it to nearly every point of the compass. Buffalo River is the largest stream. It rises in Lewis and Lawrence counties, flows across the southern portion of Lewis, and empties into Duck River, in Humphreys County. Among the smaller streams may be mentioned Big and Little Swan Creek, Cane Creek, Trace Creek, Rockhouse Creek, Grinders Creek, Chief Creek, Indian Creek, and many others too numerous to mention. For the names and locations of these the reader is referred to the county map accompanying the report.

ECONOMIC RESOURCES.

While this paper is primarily a discussion of the iron ores of Lewis County, it will probably be of interest to mention a few of the other economic resources occurring in this area. The most important minerals occurring in the county are iron and phosphate rock. Of minor importance are building stone and limestone for flux, lime and fertilizer, and a variety of rock suitable for road material, and clays. The future possibilities of much of the so-called sterile, siliceous soils are little understood and appreciated. The same may also be said regarding the utilization of the abundant undeveloped water power found in nearly every part of the county. The products of the forests have been and are still an important resource of the county.

Phosphate.—The first workable deposit of bedded blue phosphate rock discovered in Tennessee is said to have been located by the Hon. J. W. Whitthorne, in December, 1893, on Upper Swan Creek, in the eastern part of Lewis County, in what is now the Gordonsburg mining district.*

*For detailed information and maps concerning the phosphates of this region, the reader is referred to two articles by C. W. Hayes of the U. S. Geological Survey: 16th Annual Report, U. S. Geol. Surv., part 4, pp. 610-630, 1895; and 17th Annual Report, U. S. Geol. Surv., part 2, pp. 513-550, 1896.

Digitized by Google

The method of mining is somewhat similar to that employed in working coal beds, as it is all underground and conducted by tunnelling. The phosphate strata run from 24 to 36 inches in thickness.

The blue rock is a bedded deposit and usually occurs between hard shale ("slate") and limestone strata, which form the roof and floor of the mine. Commercial deposits of the brown and white rocks are not known to exist in this county. It is found in intermittent seams varying from 0 to 25 inches in thickness, but where mined is usually about two feet thick. The bone phosphate of lime will range from 30 to 85 per cent, with varying amounts of the injurious ingredients, iron and alumina.

The question is often asked how a phosphate rock can be determined. The following simple test by F. B. Van Horn* will be found useful: "Place a small crystal of ammonium molybdate on the rock to be tested, then drop a little dilute nitric acid on the crystal. If the crystal turns yellow, it indicates the presence of phosphorus. The deeper the yellow the higher the phosphate content."

Soils.—The soils of Lewis County may be classified according to their mode of origin into two kinds: namely, transported (alluvial and colluvial) and residual soils. The residual soils are those resulting from the decay and disintegration of the rocks outcropping at the surface, while the transported soils are those which have been removed, mainly by water, from the place where formed to another locality. The soils occurring in this county are mostly residual, for the alluvial or bottom land types have a very limited development. The most productive soils are the gravelly and silt loams of the stream bottoms. These soils have a dark color due to presence of organic matter. The silt loams occur along the lower courses of the larger streams, while the gravelly loams are found in the upper parts of the streams. The other soils are residual and consist of two chief types—the more or less stony and gravelly soils of the rolling lands, and the yellow or gray silt loam soils of the "barrens" or flat lands. The stony and gravelly loam soils of the rolling lands are cultivated to some extent, especially on the north hillsides. The soils of the flat lands are siliceous and thin, and in their present conditions have a low agricultural value.

The tops of many of the ridges are covered with more or less water-worn gravel mixed with angular chert. The gravel may extend to a depth of ten feet or more, and often contains enough soil to make the area covered by it arable. The crest of the ridges and many of their slopes have such a thick covering of soil that exposures of the underlying rock do not occur, except on the lower slopes to stream valleys and in stream beds.

*Phosphate Rock, *Mineral Resources of the United States*, U. S. Geological Survey, part 2, p. 873, 1911.

Digitized by Google

The depth and character of the soil mantle has an important bearing on the iron ore deposits of the area.

Much of the so-called sterile soils of the flat lands can be made productive by a proper system of crop rotation and cultivation. These ridge soils seem adapted to fruit growing, stock raising, tobacco culture, and certain other special crops, but not to general farming, in their present condition. At the prevailing price of good farm lands in other sections of Tennessee, it is doubtful whether or not it would be profitable to improve much of these flat lands until such a time as farm lands in general become more valuable.

In spite of the damage done the timber, and the destruction to the mast, many persons living in the area still persist in firing the woods every fall. This does a great deal of harm to the soils by destroying the leaves and decayed timber that would otherwise be transformed into vegetable mold (humus), which is so necessary to make these soils productive. These lands are also greatly deficient in lime.

Water power and timber.—The water power and timber resources of this county have already been referred to. There has been reported to be quite a number of streams in this county having a fairly constant supply of water, rapid fall, and good banks. These would afford favorable sites for small water power developments. Among those streams suitable for the generation of power by water may be mentioned Buffalo River, Little Buffalo Creek, and Chief Creek.

Lewis County was once covered with forests, from which most of the merchantable timber has now been removed. However, much of the county is covered with second growth timber which will doubtless be of considerable value in the future. Among the most important forest types are the white oak, post oak, chestnut oak, red oak, several varieties of poplar, several species of hickory, walnut, beech, chestnut, and maple. A considerable quantity of the timber was formerly manufactured into charcoal, which was used in reducing the ores in the furnaces, but practically all the furnaces now use coke.

IRON.

Iron belts.—Many years ago Dr. James M. Safford,* then State Geologist of Tennessee, had the following to say regarding the iron ores of this state:

"The variety and the aggregate amount of iron-ore in Tennessee, its excellent quality, its favorable association with the necessary conditions for the economical manufacture of iron, place the State among the best as an iron producing region.

**Geology of Tennessee*, 1869, p. 448.

Digitized by Google

"The localities and outcrops of the iron-ore of Tennessee, including all its varieties, whether in local deposits or in regular beds, are found in three belts of the State, which are quite distinct, and differ, more or less, in geological and mineral character. These belts, or iron regions, as I shall call them, are as follows:

"(A) The Eastern Iron-Region. Extends through the State, lies along with and in front of the Unaka Range.

"(B) The Dyestone-Region. Skirts the eastern base of the Cumberland Tableland, or of Walden's Ridge, from Virginia to Georgia; extends out laterally into the Valley of East Tennessee from ten to twenty miles; the Sequatchie and Elk Valleys are included.

"(C) The Western Iron-Region. Occupies a belt of the Highlands contiguous to the western valley, and a part of this valley itself; the belt runs through the State, from Kentucky to Alabama."

Lewis County lies within the western iron ore region. This belt is about 50 miles wide and extends from northern Alabama to the Ohio River in Kentucky. It embraces an area of more than 5400 square miles in Tennessee, most of which is situated east of the Tennessee River, though it extends a few miles into some counties west of the river. It includes all or a portion of the following counties: Wayne, Lawrence, Lewis, Perry, Hickman, Dickson, Decatur, Hardin, Humphreys, Benton, Montgomery, Houston, and Stewart. More or less ore occurs at intervals over this entire region in local segregations called "banks", many of which are highly valuable.

History of the iron industry.—According to Killebrew and Safford * "There were in the Western Iron Belt, before the war, thirty-five furnaces, four bloomeries, and thirteen refineries, the latter having about fifty-nine fires. Of the furnaces, Stewart County had the greatest number; Montgomery came next; then Dickson and Decatur, each having two; and finally Hardin, Wayne, Lawrence and Perry with each one." The blast of all but two was made by steam power. Thirty-one were in operation in 1854, and made 37,283 tons of iron. The four bloomeries made 91 tons of iron. The thirteen refineries made in 1854, 6,808 tons of blooms, and a few tons of bar-iron. At that time it cost between $20 and $30 to produce a ton of charcoal iron at the furnaces, and from two to seven dollars per ton to transport the product to the railroads or navigable rivers. Eleven furnaces were in operation in the Western Iron Ore Region in the year 1873. These had an aggregate monthly production of 4,230 tons. In that year it cost less than $30 to produce a ton of cold-blast charcoal iron. During the same year it cost about $40 per ton to make cold-blast charcoal metal in Pennsylvania, Ohio, and Indiana.

Within recent years, the production of iron in the western Highland Rim has declined, due chiefly to close competition from other parts of the

Resources of Tennessee, 1874, p. 237.

Digitized by Google

country. According to the reports of the State Mining Department, this region produced, in 1912, 226,407 tons of ore, and 104,766 tons of pig iron; in 1913, 134,887 tons of ore, and 64,256 tons of pig iron. The falling off in 1913 was due to the general depression of business.

The only furnace in Lewis County is located at Napier on Chief Creek, in the southeast portion of the county, and about ten miles southeast of Hohenwald. Killebrew and Safford* have the following to say in regard to the early history of this furnace and mine:

"Napier's Furnace, the only one now in operation in Lewis County, was first erected in 1834. It was leased in 1873 by Ward, Rains & Co., and put in operation on the 15th of September. During the remainder of the year it made about nine tons of pig metal per day, at a cost of about $24 per ton, but this cost, the superintendent thinks, may be reduced to $18 by having a sufficient amount of stock on hand to run for ten months. Wood choppers are paid from sixty to seventy-five cents per cord, and day laborers $1.50 per day, they feeding themselves. About 200 bushels of charcoal is consumed in making a ton of iron. * * * It is estimated that a furnace with a capacity of ten tons a day can run on the timber within a radius of three miles for thirty years. * * * It now costs $7 per ton to deliver it on the railroad at Columbia, the nearest point, a distance of thirty-three miles."

This old furnace was known as a "hillside" furnace, and was operated with charcoal as fuel. Later, a railroad was constructed to Carpenters Station, and the pig iron was hauled in wagons to that point. About the year 1890, the Napier Iron Works secured the property. A railroad was then built from Summertown, Tennessee, to Napier, Tennessee, and a new furnace was constructed. This furnace was operated with charcoal as fuel until 1897, when changes were made in the plant equipment and coke substituted for charcoal. In 1904 the mining of ore was discontinued at the Napier mine. Since that year the supply of ore for the Napier furnace has come from its Wisdom Ore Mines (Sharp Mine) near Pinkney, Tennessee, and since 1897, its supply of coke has come from the Virginia field. Recently, however, the Napier Iron Works has installed a modern steel log washer with crushers and jigs, and have resumed operations at the Napier mine. The output of the mine for the year 1912 was 10,385 long tons, with 102 active days, or at the rate of over 100 tons per day. This ore had a mine value of about $1.50 per ton. Between the years 1873 and 1904 there were taken from the Napier mine from 450,000 to 500,000 tons of ore. Only one other mine is being operated in this county. It is located near Riverside, Tennessee, and joins the Bon Air Coal and Iron Company's mines at Allens Creek. The property is owned by the Warner Iron Company, and is known as the Percy mine. This mine was opened March 28, 1899, and its total production to date is about 250,000 long

Resources of Tennessee, 1874, p. 797.

Digitized by Google

tons. There is one log washer at this mine. The reader is referred to the heading, "Warner and Napier Mines" for a complete discussion of these properties.

About the year 1888 there was a rapid decline in the price of iron ore and iron products throughout the United States, principally due to the discovery of high grade bessemer ore in the Lake Superior region. This ore occurs in immense deposits, and can be mined at very low cost.

The brown ore deposits of the Western Iron Ore Region of Tennessee are numerous, and while much of the ore is merchantable, yet it is known that many of the deposits are not large enough to warrant exploitation under present conditions. These ores have attracted considerable attention within recent years, although their commercial importance has been recognized for over half a century.*

GEOLOGY.

General statement.—The rocks of this area are all of sedimentary origin. The strata range in age from Ordovician to Lower Carboniferous, inclusive, and comprise a variety of limestones, shales, and sandstones. The geology of the northeastern part of the county has been worked out by Hayes and Ulrich, and described in the Columbia folio of the U. S. Geological Survey to which the reader is referred for a full description. Further description of the geology which partially includes Lewis County may be found in two articles published in the *Resources of Tennessee.* One is by N. F. Drake †, "Economic Geology of the Waynesboro Quadrangle", and the other is by Bruce Wade‡, "Geology of Perry County and Vicinity". These include southwestern and western portions of the county.

THE IRON ORE DEPOSITS.

Topographic relations.—The iron ore deposits have a well defined and striking relation to the topography of the region, being located on or near the crests of the ridges and spurs of the inter-stream divides. They have approximately the same elevation, and any noticeable difference in elevation are apparently due chiefly to the amount of denudation the locality has suffered.

Geologic relations.—The ridges and their spurs are generally covered with a thick blanket of residual clay soil, containing fragments of partly weathered, and often bleached, cherts and siliceous limestones. This soil

*For statistics on iron ore production consult the annual reports of the Chief Mine Inspector, Mining Department, State of Tennessee.

†Volume IV, No. 3, pp. 99-120.

‡Vol. IV, No. 4, pp. 150-181.

Digitized by Google

mass is chiefly derived from the weathering of the underlying limestones and cherts of the St. Louis and Tullahoma formations. Water-worn quartz and chert gravels, and what appears to be alluvial sands. sandstones, clays, and shales are frequently intermingled with the residual soil mass. In some exposures layers of cherty limestones overlie the water-worn gravels, but no conglomerate from which the quartz and chert gravels could have been derived has ever been found in this region. The gravel seems more abundant near the top of the mass, and apparently decreases with depth. It, however, is patchy in its occurrence. More or less occurs, with rare exceptions, in the loose mass containing the ore, but in a few instances, the ore is found in very red clay containing little or no gravel and chert. The apparent abundance of gravel near the top is, in most cases, doubtless due to the clay soil having been removed by erosion, thus leaving the more resistant gravels.

In the mass containing ore deposits there is no clearly defined arrangement of materials. The bedded rocks, that sometimes occur, do not appear to occupy their original position. The whole mass has a jumbled appearance. Doctor A. H. Purdue * has suggested that the bedded material came to its present position by landslides. The loose material overlying the solid rocks varies from a few feet to over 100 feet in thickness, and has, in most cases, a considerable thickness in this area. It is in the loose material, as a matrix in which the iron ore deposits of the region occur.

Observations in this area seem to show that probably most of the deposits occur in the loose material at approximately the same geological horizon within the St. Louis limestone. This, however, is rather difficult to determine, on account of the thick covering of soil usually found in this area, and the nature and position of the material in which the ore occurs.

Mode of occurrence.—The ore is found accumulated at certain centers which are called "banks". The upper portion of the bank is called the "top clay", which varies from nothing to over 15 feet in thickness. The upper part is often of a yellow or grayish color, while the lower portion is always very red, and contains more or less "shot ore". The shot ore is less than an inch in diameter and is of irregular size and shape, but usually somewhat rounded. It is rich in iron, and often occurs in the clay in such abundance as to make it workable. Large fragments of ore more than 10 feet in diameter sometimes occur in the top clay. Some of these are highly siliceous, containing a considerable amount of gravel and angular chert, while others may be very rich with limonite. The shot ore and

**The Resources of Tennessee*, Vol. 2, No. 10, p. 382, 1912.

Digitized by Google

the clay are formed by the weathering of the larger fragments of ore and the associated rocks.

Beneath the top clay, the ore is found aggregated in irregular bunches or pockets of varying richness, and these are separated by more or less barren material. They are of all dimensions from less than 10 feet up to masses over 40 feet in diameter, and may assume various shapes and positions. Many are tabular and approach the horizontal, but they may be inclined at any angle. The ore sometimes occurs in isolated lumps called "pots". The pots are lenticular shells, which vary from a few inches to more than 25 feet in their longest dimensions. The smaller ones are sometimes hollow, but frequently they are partly or completely filled with water, decomposed chert, a white or yellowish powdery clay, or tough, fat clay. The larger shells may inclose one or more of the following substances: Clay, gravel, sand, and angular chert. The larger pots sometimes have the appearance of irregular veins winding through the banks in different directions. Large chunks of conglomerate and breccia frequently occur cemented with hydrous iron oxide (limonite). These appear to be more abundant near the top of the bank, but may occur elsewhere. An iron-stained, soft sandstone is sometimes met with. Masses of ore frequently surround or partly cover a "white horse" or "yellow horse", which is a putty-like, residual clay that becomes extremely sticky when wet, and can not be easily separated from the ore in the washer.

Size.—Some of the banks of the Western Iron Ore Region occupy an acre or less, while others cover several square miles. The deposits of Lewis County will vary from banks less than an acre in extent to those covering over 500 acres. However, these large banks must be thought of as numerous deposits or local segregations of varying richness. The worked deposits often supply a large amount of ore before they are exhausted. In the excavations if a mass is struck it is followed until it disappears, when another is sought for.

Depth.—The depth of the ore varies greatly, even within the same bank. Developments have shown that while some deposits may be less than 15 feet deep, others are 60 feet or more. The workings at the Nunnelly mine, in Hickman County, have reached a depth of over 60 feet, and a shaft put down 60 feet further is reported to be in ore-bearing ground. The bottom of the ore in the Napier mine has not been reached at a depth of 45 feet. The lowest limits of the ore bodies at the Bon Air Coal and Iron Company's mine, near Allens Creek, and of the adjoining Perry mine, near Riverside, have not been found at a depth of 60 feet. The openings at the Ætna Mine, located at Ætna, Hickman County, have reached a maximum depth of about 40 feet. Here, test pits sunk a few feet deeper

Digitized by Google

in the old workings have not reached the bottom of the ore deposits. The greatest possible depth at which the ore can occur will depend upon the thickness of the loose material overlying the solid rocks, for pay ore has never been found in the bedded rocks.

Outcrop.—Outcrops vary greatly in size and form, and frequently indicate the nature and value of the deposits. Some outcrops will extend over less than ¼ of an acre, while others will occur more or less continuously over several hundred acres. However, in many cases the size and character of the outcrops are insufficient criteria upon which to base a reliable estimate of the size and value of a bank. Valuable deposits have been found to underlie areas showing little or no surface indications. In such cases more or less soil or gravel overlies the ore body. No doubt there are local segregations of ore many acres in extent that do not show at all or appear on the surface. Such deposits doubtless exist in the flat ridge lands where the soils have a considerable thickness, and in other favorable situations where erosion has lagged behind rock weathering.

A promising form of outcrop consists of chunks of ore embedded in the soil with the surface of the ground strewn with either or both large and small fragments of ore, and the subsoil very red and containing a considerable quantity of shot ore. Other things must be taken into consideration, such as the depth of the material overlying the solid rocks, and the elevation and extent of the workable deposit.

A less promising form of outcrop consists of a ledge of highly siliceous and massive conglomerated and brecciated ore protruding from the side of the hill or ridge. These ledges are sometimes 20 feet or more in thickness, and from a few feet to over 150 feet in length. The ore underlying such outcrops is usually of a very inferior quality, and of little or no commercial value at the present time.

Overburden.—The overburden varies in thickness from a few inches to over 30 feet. It usually consists of clay, water-worn quartz and chert gravels, and angular chert, but may consist only of clay or both clay and chert. The tops of the ore bodies are nearest the surface on the points of the ridges and their spurs, and in other situations where the soil has been largely removed by wash. In the flat lands or so-called "barrens" the ore is well concealed beneath 10 feet or more of clay soil, or soil and gravel.

THE ORE.

Mineral composition.—The ore is limonite or so-called brown ore. In some instances it is probably a mixture of goethite, turgite, and limonite. Limonite has been called brown hematite, and bog iron ore and ochre are types of it. The mineralogical composition of limonite is $2Fe_2O_3 3H_2O$.

Digitized by Google

When pure, it contains 14.44 per cent. of combined water (water of constitution), and 85.5 per cent. of oxide of iron (=59.89 per cent. of metallic iron). The water of constitution (not to be confused with ordinary wetness) is not driven off under a dull red heat; but it is driven off at red heat, when the ore becomes hematite and contains 70 per cent of metallic iron. The ordinary water adhering to it is given off at boiling temperature. As the theoretical percentage of pure limonite is 59.89 per cent. of metallic iron, it never contains more than 59.89 pounds of iron in 100 pounds of ore. In fact, it is never pure and never contains this amount owing to impurities. Goethite and turgite contain less water of combination, and when pure, have a slightly higher percentage of metallic iron. Limonite is recognized principally by its yellowish-brown streak and absence of crystallization. Its color is light-brown to dark-brown or nearly black. Many of the compact varieties have a smooth, black, varnish-like surface, but on fracture often show a fibrous radiated structure, and a somewhat silky lustre. Small quantities of oxide of manganese frequently occur in the ore. It is usually in the form of the mineral wad.

The chief mineral impurity is silicia in the form of sand, chert, and crystalline quartz. Sand occurs intermixed or embedded in the ore, filling cavities, and as the matrix of a limonitic cemented, soft sandstone. Sand appears to be more abundant near the top of the ore deposits, and in the outcrops, than in the deeper ore. The sand, filling cavities, can be removed by crushing and washing, but when it occurs in the other forms it generally can not be successfully removed by this method. Large and small fragments of weathered chert often occur embedded in the ore. These inclusions may be, in part, removed by crushing and washing. The ore frequently occurs as a cementing material of cherty breccia, or as the matrix of a conglomerate, the pebbles of which are quartz gravels and partly decomposed chert. Such impurities can often be partly removed by crushing and washing, but the low grade, highly siliceous ore has no commercial value at present. The clay adhering to and surrounding the ore can be largely removed by washing.

Chemical composition.—On account of the rather high phosphorus content the ores of the Western Iron Ore Region fall in the Basic-Bessemer and Basic-Open Hearth classes. Much of the ore of this region is of excellent quality and makes a good grade of iron that can be used for many purposes. It is equal, if not superior, to the brown iron ores of any other state. The phosphorus content will range from about 0.166 to over 1.916 per cent., with an average of about 0.747 per cent. The metallic iron will average about 50.78 per cent. The content of silica ranges from near 3.97 per cent. to excessive amounts with an average of perhaps 12.71 per cent.

Digitized by Google

The ore is uniformly low in sulphur, which is a desirable feature. The average sulphur content of 39 samples analyzed by the Survey was found to be 0.049 per cent. The manganese percentage may run rather high in exceptional cases, which is an advantage when the iron is used for certain purposes, but usually it is present in small amounts ranging from 0 per cent. to over 4.00 per cent.

Physical characters.—The ore varies from dense, compact forms to soft and earthy varieties. A common form is a porous or cellular, dark-brown, rather hard limonite locally known as "honey comb" ore, which frequently has a cindery-like surface. Another very common form is the hard, compact bowlder or chunk ore. It breaks with a conchoidal, splintery fracture. Both the cellular and compact varieties may enclose small, light-colored angular chert fragments and some sand, but such inclusions are more abundant in the porous or cellular forms. The quantity of chert present varies from an occasional fragment to where the ore becomes iron-chert breccia, in which case it has no commercial value. The ore sometimes occurs in the stalactitic or "pipe" form, but this form of the ore is not known to occur in workable quantity in Lewis County. The pipe ore is usually very pure. It may occur as single individuals, but more often in parallel aggregates, forming bundles.

FIG. 1. From left to right: Highly cherty cellular limonite; pipe ore; and cellular limonite. The size of the minerals may be estimated from the book upon which they rest.

ORIGIN OF THE ORES.

It is quite evident that the history of the ore is closely associated with the origin of the water-worn quartz and chert gravels, angular chert and limestone fragments, and what appears to be alluvial sandstone, sand, clay, and shale. This material, with the exception of the quartz gravels,

Digitized by Google

has been largely derived from the St. Louis formation. The source of the quartz gravels is not known nor is there known to exist a conglomerate in this region from which the gravel could have been derived.

The lack of any well defined arrangement of the material indicates that most of it is probably a valley-filling material that has been transported short distances by shifting, aggrading streams, but the somewhat jumbled appearance of the entire mass suggests a landslide origin for a portion of it.

That the ore has been deposited in its present form and has not been derived from the oxidation of pyrite or marcasite seems beyond question. The absence, so far as known, of iron sulphides or pseudomorphs after the sulphides would indicate that the ore is not of secondary origin. The physical and chemical characters, topographic relations, and wide areal distribution, for ores of similar character over a rather extensive territory, would suggest a bog origin. However, the following facts indicate that the ore is, at least, not directly of bog origin:—The ore bodies may dip at any angles or may lie horizontal, and the depth to which it extends may vary greatly, even within the same deposit. It may surround or cover residual clay. Large and small fragments of chert and limestone frequently occur in it. Some of the ore appears to have concentrated by circulating ground water, but much of it appears to have been derived mechanically from previously existing deposits. Years ago Professor Safford * suggested that the banks were probably derived from chalybeate springs which issued from the hillsides on either side of the valleys, but until more detailed investigations are made, the origin of these deposits must remain an open question.

PROSPECTING.

The ore, in most places, is usually covered by soil, gravel, and sand, so that outcrops do not occur except in such favorable situations as around the head of hollows and gullies and near drainage ways or streams where the overburden has been removed by erosion. It thus follows that in the high flatlands there may be local segregation of ore of workable size that do not appear at the surface.

Experience has shown that a search for brown ores in this part of Tennessee should be confined to the highest lands. In the absence of ore outcrops, the intense red color of the soil and the presence of float shot ore are valuable criteria which often indicate a probable bank. In wooded areas, however, the color of the soil is often hidden by vegetation. In such situations the roads, trails, and other surface features bare of vege-

*Geology of Tennessee, p. 350.

Digitized by Google

tation, the upturned roots of trees and the holes of burrowing animals should be carefully examined for iron ore. Fragments of ore scattered over the surface, and residual ore embedded in the soil, indicate a bank beneath. After all surface indications have been carefully examined, the prospect should be proved by sinking test wells or shafts, for the surface indications of limonite deposits do not afford a true index to the size and commercial importance of the bank. The careful sinking of a requisite number of test wells at proper intervals would determine the lateral and vertical extent of the ore, its quality, and the thickness of the overburden. The prevailing method of sinking wells and pits is by hand, in which the windlass, rope, bucket, shovel, and pick are used. The wells should be sunk to a depth of 20 feet or more, depending upon the thickness of the unconsolidated material overlying the solid rocks, for the ore is not known to occur commercially in the stratified rocks. The most economic size of shallow pits is probably 2½x2½ feet, and of deep ones, 3 feet in diameter. Very siliceous ore (gravelly, sandy, and cherty) may occur in the upper portion of a bank while that at lower depths may be of a good quality, so that considerable judgment is necessary in determining the value of a deposit.

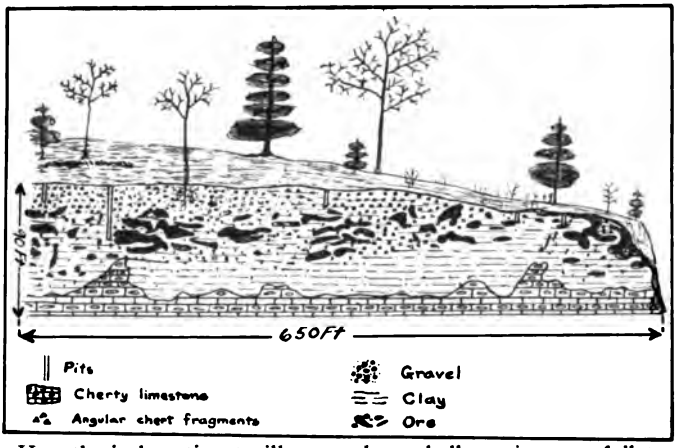


FIG. 2. Hypothetical section to illustrate how shallow pits may fail to show ore on the crest of a ridge where the overburden is thick.

A good topographic map is exceedingly valuable in prospecting for brown ores and in development work. Such a map will show the vertical and often the probable lateral range of the deposits and their relation to the drainage. Many other valuable features will be brought out in a map having the proper contour interval and scale.*

*A detailed description of the methods of prospecting for iron ore is given by E. F. Burchard, in "The Production of Iron Ore, Pig Iron, and Steel", advance chapter from Mineral Resources of the United States, U. S. G. S., 1911, p. 24.

Digitized by Google

UNIV. OF MICH.

Digitized by Google

Digitized by Google

MINING AND CONCENTRATING METHODS.

Mining operations are comparatively simple, owing to the shallow nature of the deposits. All the workings are open cuts. The ground is loosened by picking and blasting. Steam shovels are used in the large banks, and the ore is usually transported to the washer on mine cars hauled by a steam locomotive. The small deposits can often be profitably worked by the hand method and the ore trammed to the washer in wagons, provided the deposit is rich and the washing plant is nearby. However, many of the deposits are too small to support expensive equipment, and these can not be profitably worked unless mining is done in connection with the larger banks. The ratio of the ore to waste varies from about 1 to 3 in the richer deposits to about 1 to 10 or 12 in the poorer deposits. The lowest that can be profitably worked at the present time is about 1 to 10.

FIG. 3. Steam shovel work in an iron mine of the western Highland Rim.

The ore is concentrated in modern steel log washers. It is transported in wagons or mine cars to the tipple, where it is dumped on grate bars. There the large fragments and bowlders are broken up so that it can pass into an inclined metal-lined flume in which a stream of water is constantly flowing. The water forces the ore down the flume into the washer, which automatically removes most of the waste from the ore. Some of the coarser material which is not separated by the washer is removed by hand, as the ore passes along on a belt towards the storage bins. The chief

Digitized by Google

equipment for a modern steel log washer will consist of two logs, sizing screens, crushers, jigs, receiving bins, distributing trammels, picking belt, and a complete pumping station. Water is obtained from the numerous creeks found in this section of the State. The residue from the washer passes into settling ponds, from which part of the water may be used over again.*

FIG. 4. Chemical laboratory and furnace at the Napier mine.

NOTES ON MINES AND PROSPECTS BY LOCALITIES.

INDIAN CREEK DEPOSITS.

The Indian Creek deposits are located in the vicinity of Indian Creek, in the northeastern part of the county. The location of these is shown on the accompanying topographic sketch map.

PEELER AND CARROLL BANK.

(*No. 1, Lewis County map.*
Owned by J. M. Peeler, W. A. Carroll and others, Hohenwald, Tennessee.)

This bank, located 3½ miles south, 80 degrees east of Kimmins, is situated on the top of a rather narrow ridge and its spurs. This ridge lies on the north side of Indian Creek, and northwest of the fork of the Indian Creek and Aetna roads. Its elevation is between 800 and 850 feet above sea level.

The top of the ridge is about 200 feet above the bed of Indian Creek. Cherty limestones of the Tullahoma and the overlying St. Louis formations outcrop on the lower southern slope of the ridge and extend up its side through a vertical distance of approximately 70 feet. The rocks are nearly horizontal. The ridge is capped by residual material, consisting of clay and partly decomposed, angular

*For a complete discussion of the methods of treating brown iron ores, the reader is referred to an article by H. S. Geismer, *Bull. Am. Inst. Mining Eng.*, No. 56, 1911, p. 642.

Digitized by Google

chert, containing some water-worn gravels. It is in this loose material that the iron ore occurs. The thickness of the loose material overlying the solid rocks is evidently less than 130 feet, though weathering apparently extends to a considerable depth.

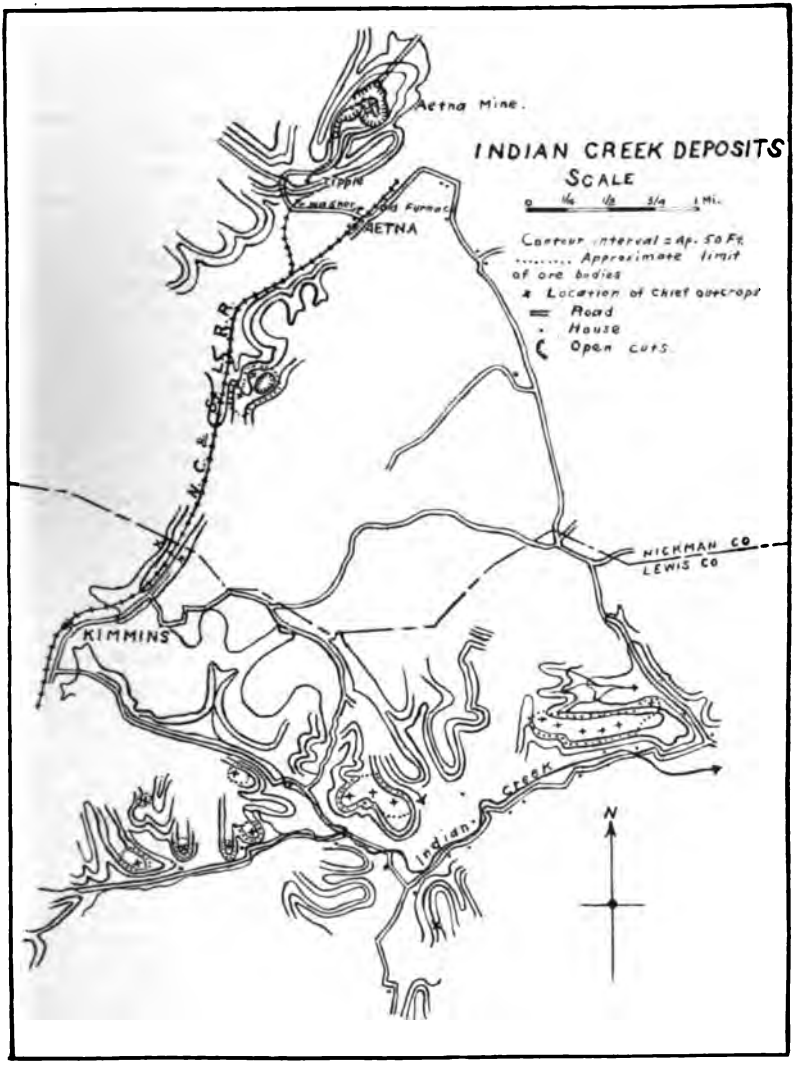


FIG. 5.

More than 16 shallow test pits, covering one area of 10 or 12 acres, have been dug on and near the top of the ridge. The depth of most of the pits is between 3 and 4½ feet, though a few are 8 to 10 feet deep. Six of them are blank, or show a little shot ore in very red clay. Most of the 10 remaining ones show a fair

Digitized by Google

quantity of ore, and 5 of the 10 make an excellent showing. On this ridge is a small, shallow cut from which a few wagon loads of ore were hauled to the old Aetna furnace when it was in blast. The material thrown out of the test pits consists of ore, very red clay, angular chert, and some water-worn gravel. The surface of the ground is in places more or less covered with fragments of ore, and shot ore is especially abundant. Some rather large chunks were seen on the slopes of the ridge and others are embedded in the clay. A few were found 30 feet below the crest of the ridge and apparently in place.

The test pits and outcrops indicate that some good deposits may be found over an area of 20 to 25 acres. Erosion has apparently brought the ore deposits near the surface, so that the overburden should not be excessive. The limonite seems to be of good quality, and is generally free from excess of sand, chert, and gravel. The ore is chiefly in the form of shells ("pots") and solid lumps. An average sample taken from several of the pits analyzed * 54.29 per cent. iron, 8.62 per cent. silica, .166 per cent. phosphorus, and .009 per cent. sulphur. A sample taken from several pits on Carroll's land analyzed 53.73 per cent. iron, 8.59 per cent. silica, .347 per cent. phosphorus, and .047 per cent. sulphur.

BAKER'S PROSPECT.

(No. 2, Lewis County map.
Owned by A. L. Baker, Hohenwald, Tennessee.)

This prospect is located 2¼ miles south, 45 degrees east of Kimmins, and on the south side of Indian Creek. It is situated on the west side of a very narrow secondary ridge at approximately 50 feet below its crest. At this place a very shallow excavation was made into the side of the hill, and the material piled up near the place showed a considerable amount of ore for a shallow cut. The ore seems to be of fair quality and comparatively free from foreign material. The top of the ridge is about 150 feet above the bed of Indian Creek, and considerable gravel was observed on its crest. No indications of ore were found, except the one mentioned above. Surface indications have been reported on several ridges ¼ of a mile or more east of this locality.

LANGFORD AND LONG BANK.

(No. 3, Lewis County map.
Owned by J. R. Langford, Hohenwald, Tennessee, and Charles Long, Mt. Pleasant, Tennessee.)

This bank is located on the north side of Indian Creek, 2 miles south, 60 degrees east of Kimmins. The ore deposits occur on and near the top of a secondary ridge and its spurs. The top of the ridge is approximately 160 feet above the bed of the creek. A 40-foot section of rocks was observed on the south slope of the ridge, extending down to the creek. It thus appears that the loose material in which the ore occurs might extend to a depth of 120 feet, though such is not probable.

Eight shallow test pits and a shallow cut were found scattered over an area of possibly 25 acres. These pits have been dug on or near the top of the ridge. They vary in depth from 4 to 8 feet, and most of them show a fair quantity of ore. Angular chert fragments and some water-worn gravel occur mixed with the clay and

* All analyses herein quoted were made by Dr. Paul C. Bowers, Chemist of the State Geological Survey, unless otherwise stated.

Digitized by Google

ore from the pits. The clay subsoil exposed in the pits is very red and is frequently rich with shot ore. This ridge contains a shallow cut from which a few wagon loads of ore were hauled to the Aetna furnace when it was in operation. Shot ore is abundant on the top and slopes of the ridge, and larger fragments of ore occur embedded in the soil, and as float. A few large bowlders of iron-cemented conglomerate and breccia were observed.

The ore appears to be of good quality and largely free of siliceous impurities. It is mainly in the form of pots and compact varieties. An average analyses from eight samples gave 51.77 per cent. iron; 10.60 per cent. silica; .859 per cent. phosphorus; and .031 per cent. sulphur.

The surface indications and test pits seem to show that the ore occurs in pockets of varying richness over an area of 20 acres or more. The property should be systematically prospected.

THE COBLE PROPERTY.

(*No. 4, Lewis County map.*
Owned by J. D. Coble.)

This property is situated on the southwest prong of Indian Creek, 1½ miles south, 40 degrees east of Kimmins. The iron ore bank occurs on the southeast point of a narrow secondary ridge, and there are also surface showings on an adjoining southwest point. No outcrops of stratified rocks were found. The points of the ridge where the ore outcrops occur are about 125 feet above the small stream at their base. Several shallow excavations were found on the edge of the southeast point, and the writer was informed that a few wagon loads of ore were hauled from these cuts to the old Aetna furnace. Here the ground is strewn with residual ore fragments. The clay in the excavations is very red, and contains a large amount of ore, principally shot ore, in its upper part. A few large chunks of residual ore were seen. A considerable quantity of float ore, and also ore embedded in the soil, was found on the edge of the southwest point. The intervening space between the points make a poor showing for much ore. The southeast point shows up better than the southwest one. The indications are favorable on 3 or 4 acres on the southeast point of the ridge and on one or more acres on the southwest point. The ore probably extends to a depth of at least 20 feet. An analysis of the ore gave 53.40 per cent. iron; 8.26 per cent. silica; .952 per cent. phosphorus; and .044 per cent. sulphur.

SMITH BANK NO. 1.

(*No. 5, Lewis County map.*
Owned by Frank Smith, Pasadena, California.)

The deposit is located on a southwest prong of Indian Creek, 1½ miles south, 15 degrees east of Kimmins.

The bank is situated on and near the top of the point of a long, narrow secondary ridge. The top of the ridge is about 100 feet above the small stream near its base. The ore occurs in the loose material overlying solid rocks, but no rock outcrops were observed. However, chert fragments were abundant near the base of the ridge and these indicated the presence of the St. Louis formation. Water-worn gravel is abundant on the crest of the ridge north of the ore deposits.

Developments consists of two shallow pits on top of the ridge, and these show a fair quantity of good ore in very red clay. The larger pit is 20x10x8 feet, and the smaller pit is 5½ feet deep. Several wagon loads of ore are reported to have

Digitized by Google

been hauled from these cuts to the old Aetna furnace. Ore fragments are scattered over several acres on the top and upper slopes of the ridge. Massive conglomerate cemented with limonite, outcrops on the south slope, and a large quantity of water-worn gravel was noticed at this place.

Surface showings are good over 3 or 4 acres, and these indicate that the ore pockets extend to a depth of at least 15 feet. An analysis of the ore gave 50.73 per cent. iron; 13.79 per cent. silica; .614 per cent. phosphorus; and .032 per cent. sulphur.

SMITH BANK NO. 2.

(No. 6a, Lewis County map.
Owned by Frank Smith, Pasadena, California.)

One-fourth of a mile east of the ridge described above is an excellent prospect for a small bank. This is also a narrow ridge about 100 feet higher than the valley.

The property shows several small, shallow cuts from which ore is said to have been hauled by wagons to the old Aetna furnace. The largest cut is 25x20x10 feet. The cuts are on the point of the ridge, and all show ore in very red clay. Most of them make an excellent showing. Several shallow excavations on the slope of the ridge, 40 to 50 feet below the top, show a large quantity of ore. Large solid chunks of ore, which appeared to be in place, were seen embedded in the clay soil 30 feet or more below the crest of the ridge. Large bowlders, some over 3½ feet in diameter, of limonite-cemented conglomerate and breccia, occur on the slope of the ridge. Some iron-stained blocks of sandstone also occur. The point of the ridge is covered with shot ore and larger fragments of ore. Some of the solid chunks are heavy with iron.

There is probably a good small iron ore bank in this ridge, and the indications are favorable over at least 4 to 5 acres. Judging from the large chunks of residual ore and ore in the pits below the crest of the ridge, it is likely that the ore pockets extend to a depth of 45 to 50 feet. Most of the ore is in the form of solid chunks and pots. There is also a little honeycomb ore.

(No. 6b, Lewis County map.)

Two-fifths of a mile north, 40 degrees west of the above bank, ore outcrops on top of a ridge, near a draw. The outcrop covers an area of several hundred square feet, but no prospecting has yet been done in this locality.

A PROSPECT NORTH OF THE COBLE PROPERTY.

(No. 7, Lewis County map.)

This prospect is located on the northwest prong of Indian Creek, 1¼ miles south, 50 degrees east of Kimmins, and ½ mile north of the Coble property. Several very shallow pits have been dug on the crest of a ridge whose elevation is about 125 feet above the bed of the creek. All the holes show some ore, chiefly shot ore, and two of them make a good showing. In places, the surface of the ground is covered with shot ore. No large chunks of ore were found here. The last dirt thrown out of the holes is very red clay containing shot ore in more or less abundance, and some chert fragments.

The test pits are only a few feet apart, but surface indications are fairly good over 3 to 4 acres. More test pits will have to be dug here before any opinion can be formed regarding the depth and areal extent of the deposits.

Digitized by Google

Outcrops of highly siliceous, low grade conglomerate and breccia ore, were observed on the slope of a ridge about ½ mile northwest of the above described prospect. The outcrops are only a few feet above the bed of the stream. Low grade float ore also occurs, at intervals, in or near the bed of the stream for a distance of several thousand feet north and south of this locality.

NICHOLSON'S PROSPECTS.

(No. 8a, Lewis County map.)

These prospects are located on the Nashville, Chattanooga and St. Louis railroad, ¾ mile northeast of Kimmins. A shallow excavation has been made into the side of the ridge east of the railroad track. The excavation is about 20 feet above the bed of the nearby stream, and a few feet below the top of the ridge. This cut is very shallow, but there is a good showing of ore. Small fragments of ore are abundant on the slope of the ridge near the prospect, and a few float bowlders were found in a shallow hollow about 800 feet north of the prospect.

(No. 8b, Lewis County map.)

Several shallow excavations have also been made into the side of the ridge on the west side of the railroad, and one of them shows considerable ore. The soil is red in spots near the top of the hill, and a very little shot ore was found. However, water-worn quartz and chert gravels are abundant, and apparently have a considerable thickness.

On the whole, there seems little chance of finding ore in workable quantity, at this locality, but it may be hidden beneath the thick blankets of soil and gravel of the flat lands. The ore is of fair quality.

THE SWAN CREEK SECTION.

The Swan Creek section is in the northeastern part of Lewis County. All the known occurrences of iron ore in the vicinity of Big and Little Swan creeks are described under this heading.

JENKINS BRANCH DEPOSITS.

(No. 9, Lewis County map.
Owned by the Bon Air Coal and Iron Company, Nashville, Tennessee.)

These deposits are located 3 miles south, 45 degrees east of Aetna, Hickman County, and, as shown by the accompanying topographic sketch, are situated upon the crest of a secondary ridge south of Jenkins Hollow. That portion of the ridge where the ore occurs, ranges in elevation from 700 to over 850 feet above sea level. It can thus be seen that the deposits have a vertical range of over 150 feet, but it is not assumed they are of that thickness. Practically all of the Jenkins Branch deposits are in Hickman County near the Lewis County-Hickman County line.

This bank was worked about 20 or 25 years ago, at the time the old Aetna furnace was in blast. The mine was then owned by The Southern Iron Company of Nashville, Tennessee, and was operated by them until about the year 1895, when it was sold to the Buffalo Iron Company of Nashville. The property was acquired by the Bon Air Coal and Iron Company, in July, 1902. At the time the mine was worked, the ore was hauled by wagons to the Aetna furnace at Aetna, a distance of 5 miles by the road.

Digitized by Google

The ore deposits occur in the loose material overlying the St. Louis cherty limestone formation. In this case the matrix consists almost entirely of very red clay. No outcrops of rocks were noticed in the immediate vicinity of the ore, though they occur on the lower slopes of the ridge near Swan Creek. The crest of the ridge on which the ore occurs is between 250 and 300 feet above the creek.

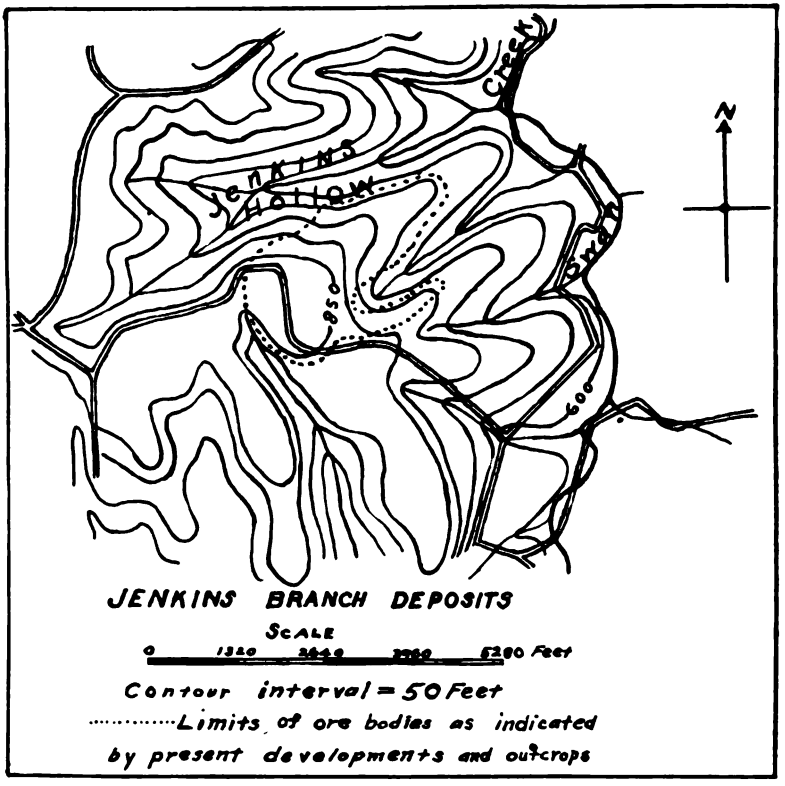


FIG. 6. Mine No. 9, of the Lewis County map.

Developments consist of more than 40 cuts and test pits. These have various shapes and dimensions, but all have nearly the same depth, which, in most cases, is less than 12 feet. The largest cut is approximately 275 feet long, 30 to 50 feet wide, and 15 to 18 feet deep. There are quite a number of cuts nearly as large as this one, but most of the openings are shallow test pits. The surface of the ground has a red cast and is more or less covered with residual ore fragments, which vary in size from shot ore up to chunks over 2 feet in diameter. All the pits show very red clay below the top soil. This "blood-red" clay is commonly rich with ore, chiefly shot ore, but ore bowlders over 4 feet in diameter occur.

It is evident, judging from the number and size of the openings, that a large amount of ore has been removed from this mine. However, only the richest and easily accessible pockets appear to have been worked. There is abundance of shot ore in the red clay, which can be profitably used under modern methods of mining.

Digitized by Google

Deep shafts should be dug, for further explorations ought to reveal some promising deposits. There is doubtless a large quantity of ore still remaining in this bank. No outcrops of solid rocks were found, and the residuum here appears to be thick, possibly exceeding 100 feet. The outcrops and pits indicate that the deposits extend over an area of 83 acres and to an unknown depth. The overburden should not be great.

The ore is a dark-brown limonite of excellent quality, being free of excessive foreign material. It is in the form of solid lumps, pots and porous honeycomb ore. The property is 4 miles from a railroad and 5 miles from the washer at Aetna. A representative sample analyzed 54.36 per cent. iron; 7.92 per cent. silica; .486 per cent. phosphorus; and .041 per cent. sulphur.

LOW GAP BRANCH PROSPECT NO. 1.

(*No.* 10, *Lewis County map.*
Owned by Dr. A. H. Grigsby, Centerville, Tennessee.)

This prospect, located 2⅕ miles north, 20 degrees west of Gordonsburg, is situated on the ridge north of Low Gap Branch. The prospect occurs on the top of a secondary ridge, and extends over several spurs. The ridge has an elevation of between 850 and 900 feet above sea level, and its crest is over 250 feet above Swan Creek.

All the test pits have been dug in a slight depression on the narrow part of the ridge where the outcrop appears most promising. In this area 5 shallow pits were found, varying in depth from 3 to 3½ feet. All except one, make a fair showing of ore. The clay subsoil in the pits is very red, and contains shot ore. Fragments of ore are scattered over the surface and extend to the point of a north spur of the ridge. Here some large chunks occur embedded in the soil and also protrude from the surface on the narrow part of the ridge. Surface indications are favorable over about 6 acres.

The ore is limonite and contains some inclusions of sand and chert. Most of the ore is of the honeycomb variety. A sample taken from the pits analyzed 52.53 per cent. iron; 12.46 per cent. silica; .876 per cent. phosphorus; and .073 per cent. sulphur.

LOW GAP BRANCH PROSPECT NO. 2.

(*No.* 11, *Lewis County map.*
Owned by The Charles Mining Company, Columbia, Tennessee.)

This prospect is located 1⅕ miles north, 3 degrees west of Gordonsburg on the point of a spur of a secondary ridge between two very small streams, at an elevation of over 850 feet above sea level. At this place masses of siliceous ore, 20 feet thick, have the appearance of a ledge extending several hundred feet around the point, about 25 feet below the top of the hill. Outcrops of limonite, consisting of bowlders and fragments, are scattered over an area of 1½ acres. Root-wads* from upturned trees contain shot ore in red clay. Some of the ore is of good quality, but the large masses are cherty. Outcrops of ore were observed around

* The editor is familiar with the word "root-wad" as applied to roots of a blowndown tree, and the earth and rocks adhering to them; but he has never seen it in literature, nor does he find it in the dictionaries. For want of a better word, it is herein used.—A. H. P.

Digitized by Google

the heads of several hollows a short distance north of this place. The locality has never been systematically prospected, and there are probably many other deposits of ore that have not yet been located. A surface sample of the ore analyzed 58.99 per cent. iron; 8.17 per cent silica; .838 per cent. phosphorus; and .035 per cent. sulphur.

THE WILSON BRANCH-CADE BRANCH BANK.

(*No. 12, Lewis County map.*
Owned by Dr. A. H. Grigsby, Centerville, Tennessee.)

This bank is 3 miles north, 40 degrees east of Gordonsburg, between Wilson and Cade branches. It is situated on both sides of the road on top of a ridge and its spurs. The ridge is narrow and has an elevation of over 900 feet above sea level, as shown by the accompanying topographic sketch.

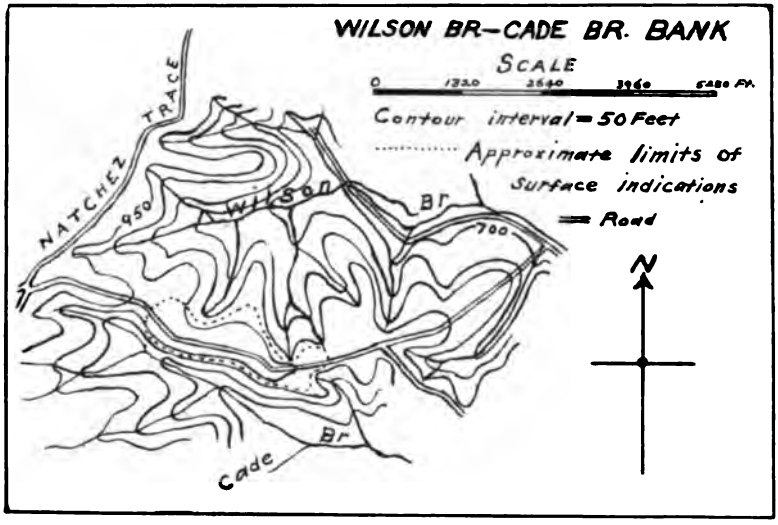


FIG. 7. Bank No. 12 of the Lewis County map.

Some prospecting has been done here, but it was not thorough, nor sufficient to prove the value of the deposits. Six very shallow test pits were found distributed along the ridge for a distance of about 2000 feet. None of the pits are over 3½ feet deep, but all, except one, show a little ore. The ore occurs in red clay, which contains chert fragments and some water-worn gravel. Small fragments of ore are abundant on both sides of the road, for a distance of 1200 to 1500 feet, and over this area the ground has a red cast in spots. Chert fragments are abundant on the ridges and on the slopes, to the hollows. The talus deposits around the heads of the hollows contain many bowlders of chert weighing over a ton. Lumps of ore can be seen in this loose rock, and some of these are more than a foot in diameter. The rock rubble also contains water-worn quartz and chert gravels, and such gravels occur in places on top of the ridge. No exposures of solid rock were observed, but the numerous chert fragments indicate the presence of the St. Louis formation. However, the thickness of the detritus overlying the solid rock is not

Digitized by Google

known, and it may be considerable here. Surface showings, as described above, extend over an area of 25 or 30 acres. The ore seen was of fair quality, but a considerable amount of rotten chert is embedded in the large bowlders. A sample of the ore analyzed 54.7 per cent. iron; 8.95 per cent. silica; .566 per cent. phosphorus; and .006 per cent. sulphur.

THE STOCKARD PROSPECT.

(No. 13, Lewis County map.
Owned by S. N. Stockard, Gordonsburg, Tennessee, and The Consolidated Phosphate Company, Columbia, Tennessee.)

This prospect, located 1½ miles south, 50 degrees east of Gordonsburg, is situated on a narrow ridge between Grinders Branch and Big Swan Creek. Here, iron ore outcrops on the crest and near the points of the ridge and its spurs, at an elevation of between 800 and 900 feet above sea level, or 200 feet above Swan Creek.

Bowlders, some over 3 feet in diameter, and fragments of limonite outcrop at intervals over an area perhaps 12 or 15 acres. The subsoil, where exposed by root-wads, etc., is often very red, and in places contains an abundance of shot ore.

Rocks of the Tullahoma formation, Chattanooga shale, and Leipers formation outcrop along the base of the ridge, and extend up its slopes for a vertical distance of 100 feet or more. These solid rocks lie nearly horizontal, and are apparently overlaid by 60 to 70 feet of loose material.

The ore is siliceous and often shows inclusions of chert fragments. Sand and gravel are sometimes mixed with it. Most of the limonite seen was in the cellular or porous form, but solid chunks occur. The ore will probably improve in quality at lower levels. Test pits should be dug at intervals over the ridge, and these should be put down to a depth of at least 20 feet. A surface sample analyzed 50.23 per cent. iron; 16.19 per cent. silica; .766 per cent. phosphorus; and .069 per cent. sulphur.

THE HARTLEY BRANCH PROSPECT.

(No. 14, Lewis County map.
Owned by The Charleston, S. C. Mining and Manufacturing Company, Mount Pleasant, Tennessee.)

This prospect is located 2½ miles south, 30 degrees west of Gordonsburg on both sides of the ridge road north of Hartley Branch. Surface indications occur on both sides of the road, on the crest of a ridge and its spurs, at an elevation of 950 feet above sea level, or 300 feet above Little Swan Creek. Two shallow test pits about 2000 feet apart, showing some ore in very red clay, were found. These appear to have been dug several years ago, and are now partly filled up. The clay from the holes contain chert fragments and gravel. Shot ore and a reddish soil occur on both sides of the road, for a distance of about 2500 feet. Throughout this distance some larger fragments of ore occur embedded in the soil and also as float, but these fragments are not abundant. A low grade, highly siliceous (very cherty and gravelly) ore outcrops around the heads of several hollows.

The ore is limonite, and most of that seen was of the cellular type, though solid lumps occur. No systematic prospecting has ever been done in this locality, and the value of the prospect is, therefore, not definitely known. No outcrops of solid rock occur in the immediate vicinity.

Digitized by Google

THE BEACH PROSPECT.

(No. 15, Lewis County map.
Owned by Fred. S. Beach, Charlotte, Michigan.)

This prospect, located 2-5 of a mile north, 68 degrees west of Newburg, is situated on the point of a spur at an elevation of 950 feet above sea level, and about 50 feet below the crest of the main ridge.

The outcrop is confined to an area of about ½ acre, and consists of bowlders of limonite, embedded in the soil, and smaller fragments of ore scattered over the surface. The ore is siliceous, and occurs in the cellular and other forms.

A considerable amount of shot ore was observed in spots on the ridge in the vicinity of Newburg, where the clay soil often shows up red in the road cuts. In several of the hollows near Newburg, large masses of highly siliceous conglomerate and breccia ore occur. Fragments of ore are also scattered over several old fields near Newburg.

THE LYON TRACT.

(No 16a, Lewis County map.
Owned by M. F. Lyon, Adrian, Michigan.)

The surface showings occur on the crest of a spur about 1000 feet north of the Lewis monument at an elevation of between 1000 and 1050 feet above sea level. Here, the ground is more or less covered with shot ore, and a few chunks of ore were seen embedded in the soil of the road. Several shallow test pits have been dug, most of which show a considerable amount of small fragments of ore. In places the surface of the ground has a red cast. Root-wads from upturned trees frequently show an abundance of shot ore. Such indications extend over 10 acres or more.

Most of the ore seen was cellular limonite, and often contained inclusions of chert. However, not enough ore was found to enable the writer to judge of the quality. A surface sample analyzed 47.09 per cent. iron; 4.86 per cent. silica; .606 per cent. phosphorus; and .04 per cent sulphur.

(No. 16b, Lewis County map.)

Surface showings also occur on the crest of another secondary ridge, which is located 2-5 of a mile west of the above described prospects. The ridge has the same elevation as the one described in the preceding paragraph, and is 300 feet above the head of Little Swan Creek. At this place shot ore is scattered over the surface, and root-wads often show a considerable quantity of these small fragments of ore. The shot ore is especially noticeable in and near an old log and tire road. No large fragments of ore were found, and the top soil is not very red. No prospecting has been done.

THE WILKINS PROSPECT.

(No. 17, Lewis County map.
Owned by Ashby Wilkins, Columbia, Tennessee.)

This prospect is located on the Palestine road 3½ miles north, 60 degrees east of Hohenwald. It is situated upon the crest of a long ridge and several of its spurs. The ridge has an elevation of between 900 and 950 feet above sea level, and is about 350 feet above Indian Creek. It is a continuation of the flat lands that surround Hohenwald.

Digitized by Google

The soil is very red for a distance of about 800 feet along the road, and shot ore is abundant in spots, or wherever the soil is of a deep red color. The soil is the reddest, and contains the most shot ore at the deepest cuts in the road. Small fragments and large bowlders of ore were found on the point of a south spur of the ridge at about 600 feet from the road. The outcrop covers an area 150 feet long by 75 feet wide. In a small ravine on the west side of this place are several wagon loads of highly siliceous, low grade bowlder ore. Only one shallow pit has been dug, but it shows some ore in red clay. Weathering has probably extended to a considerable depth on this ridge, for outcrops of solid rocks were not observed. The value of this prospect can not be estimated from showings of the one shallow pit and surface indications. The ore from the pit analyzed 54.8 per cent. iron; 6.92 per cent. silica; .675 per cent. phosphorus; and .005 per cent. sulphur.

THE NAPIER MINING DISTRICT.

The Napier mining district is located in the southeastern part of Lewis County, near the town of Napier.

NAPIER MINE NO. 1.

(No. 18, Lewis County map.
Owned by the Napier Iron Works, Nashville, Tennessee.)

This mine is located ¼ of a mile north of Napier on the crest of a high east and west main ridge and its spurs. The main ridge is really a divide between Buffalo River and Chief Creek, which streams are here only about a mile apart. The ridge has an elevation of between 900 and 950 feet above sea level. The crest of the ridge is between 150 and 200 feet above Chief Creek and about 250 feet higher than Buffalo River.

The country rocks are composed chiefly of cherty limestones, the upper portion of which belongs to the St. Louis formation. The ore is found in the detritus overlying the latter formation. Bedded rocks are exposed along the lower slopes of the ridges, and extend up their sides for a vertical distance of 50 feet or more. These rocks have never been encountered in any of the mine openings. It appears, therefore, that the loose material overlying the bedded rocks may be as much as 100 feet thick or possibly more. The bedded rocks lie nearly flat.

Iron ore outcrops around the heads of hollows, on the slopes of ridges, and in other favorable situations where the overburden has been wholly or in part removed by wash. The outcrops occur in patches over an area of at least 200 acres, and consists of bowlders, some over 3 feet in diameter, irregular-shaped masses protruding through the clay, lumps, and many small fragments. The ore is embedded in the soil or is scattered over the surface. Within the area of some of the outcrops, the ground is well covered with ore. Many test pits show ore in areas where there are no outcrops. In places, the surface showing consists of only a few isolated fragments.

The ore is found irregularly distributed through the matrix in lumps and small fragments, in various shaped masses, and in lenticular and tabular forms. The pockets have various dimensions up to masses 25 or more feet in diameter. These bunches may lie horizontal or nearly so, or again they may be inclined at any angle. Some of the pockets produce only a few tons of ore, while others will supply scores of tons before they run out. The matrix consists principally of very red clay, which contains more or less chert, and frequently water-worn gravel. The

Digitized by Google

overburden, which is composed of the same material as the matrix, varies from zero to more than 15 feet in thickness. The deposits extend to an undetermined depth, and ore in workable quantity has been found below the first workings. One of the openings has reached a depth of 45 feet.

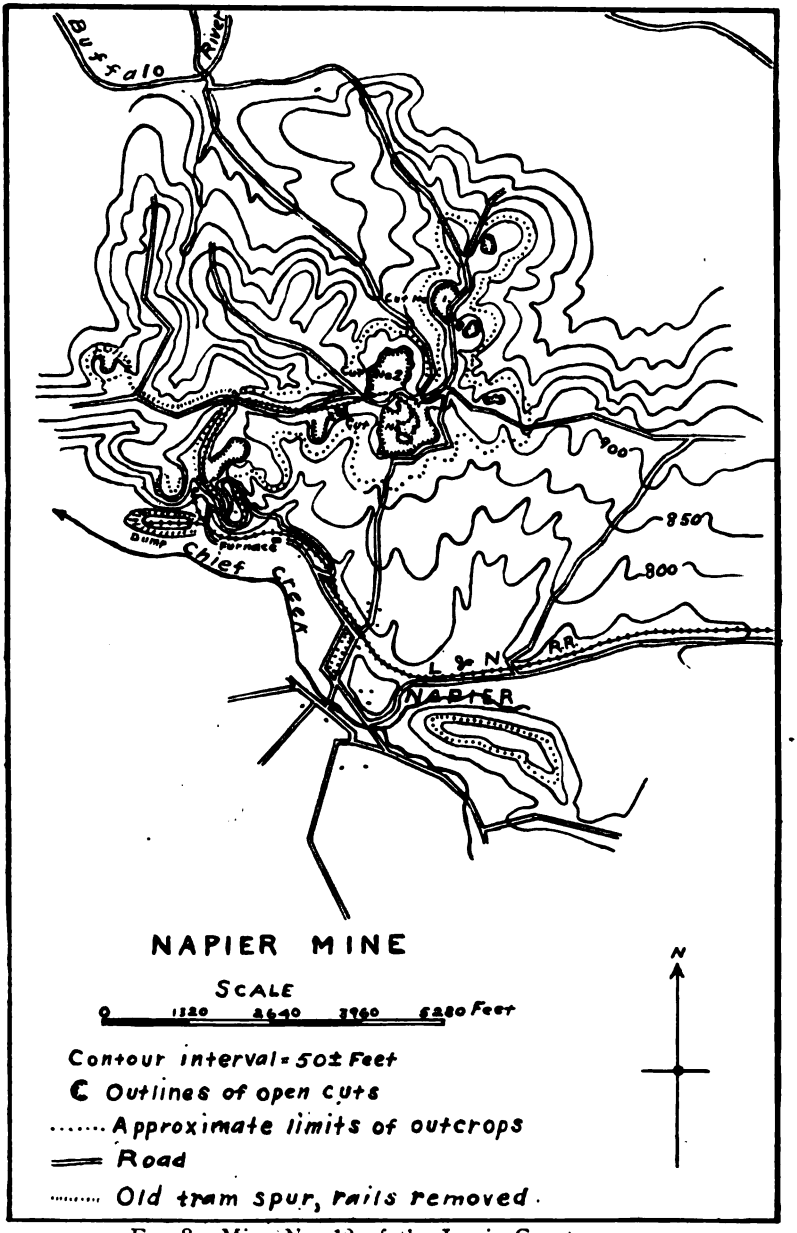


FIG. 8. Mine No. 18 of the Lewis County map.

Digitized by Google

The mine has been developed by several large, and many small openings, as shown on the accompanying topographic sketch. Most of these have been sunk to an average depth of 20 feet. Cut No. 1, one of the first opened, contains an area of 25 acres, and has an average depth of between 15 and 20 feet. Cut No. 2 covers an area of 7 acres and has a maximum depth of 20 feet. No work is being done in this cut at present. Cut No. 3 contains an area of 12 acres. It has a maximum depth of 45 feet in its north end, but over most of the pit the average depth is less than 25 feet. A steam shovel is at work in the deepest part of the cut, and here a rich pocket of ore has recently been found below the first workings. The ore at this mine is of excellent quality, being low in phosphorus.

The following extracts relating to the history of the mine and furnace at Napier were taken from an article* by Dr. A. H. Purdue, on information furnished by Mr. Wm. H. Lindsey, Vice-President of the Napier Iron Works:

"Prior to the Civil War, when that part of Lewis County in which the Napier Furnace is now located was still a part of Lawrence County, a forge was operated on the property in a small way. Somewhere near 1870 a company was formed for the purpose of taking over this old forge and of carrying on business in a strictly commercial manner, and between that time and the year 1904 there were removed from the mines at Napier from 450,000 to 500,000 tons of ore.

"In 1904 the mining of ore was discontinued by the operating company, for the reason that the facilities for handling and cleaning ore had not at that time been perfected to an extent that would warrant the company in continuing the mining of ore at that point. Recently, however, the Napier Iron Works, the present owner of the property, has installed a modern steel log washer with crushers and jigs of the manufacture of McLanahan and Stone at Hollidaysburg, Pa., and with this new and strictly modern plant it is practicable to recover ore at reasonable cost.

"The quality of ore at this mine is exceedingly fine, being low in phosphorus and high in metallic iron. The average of metallic iron will be over 50 per cent., whereas the phosphorus will run about .50 per cent. It is the anticipation of the Napier Iron Works that they will yet recover from this mine under the present operation approximately 200,000 tons of this ore.

"Prior to the Civil War the ore property at Napier was operated in a small way by private individuals in conjunction with a forge at that point. During the early 70's there was built at Napier what is known as a 'hillside' furnace, which was operated with charcoal as fuel, the wood for this purpose coming from nearby forests. The pig iron which was produced was hauled in wagons to Mount Pleasant, Tenn., the nearest shipping point at that time. Some years later the railroad was extended to Carpenters Station, and pig iron was hauled to that point until about 1890, when the property was taken over by Major E. C. Lewis, Colonel E. R. Cole and the late John Hill Eakin, and the organization of the Napier Iron Works was the result. A railroad was then built from Summertown, Tenn., to Napier, Tenn., and a new furnace was constructed. This furnace was operated with charcoal as fuel until 1897, when an additional stove and blowing engine were added to the equipment and the plant changed so as to enable it to substitute coke as a fuel in place of charcoal.

"Since that time the Napier furnace has secured its supply of coke from the Virginia field, and since 1904 the supply of ore for the furnace has come from its Wis-

* *The Resources of Tennessee*, State Geological Survey, Vol. II, No. 10, October, 1912, p. 375.

Digitized by Google

dom Ore Mine (Sharp Mine), located near Pinkney, Tenn. These mines are now being abandoned, and the ore in the future will come from its mines at Napier."

NAPIER MINE NO. 2.

(No. 19, Lewis County map.
Owned by the Napier Iron Works, Nashville, Tennessee.)

This mine which lies on the eastern edge of the town of Napier, is one mile south of Mine No. 1, and is separated from the latter by the valley of a small stream. It is situated on the top of a long and extremely narrow ridge, which is a divide between Chief Creek and one of its branches. This part of the ridge has an east and west trend, and an elevation apparently considerably less than that of the main ridge on which Mine No. 1 is located.

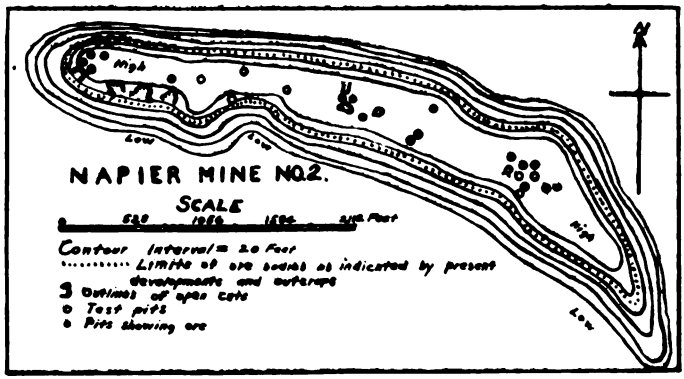

NAPIER MINE NO.2.
SCALE
Contour Interval = 20 Feet
Limits of ore bodies as indicated by present developments and outcrops
Outlines of open cuts
Test pits
Pits showing ore

FIG. 9. Mine No. 19 of the Lewis County map.

The ridge is approximately 100 feet higher than Chief Creek. A 40-foot section of cherty limestones is exposed on the lower slopes of the ridge near the streams. The thickness of the material overlying solid rocks is not definitely known, but, as indicated by the outcrops of bedded rocks, is probably 60 feet. The ore, which occurs in pockets in the loose material, lies immediately above solid rocks, but no exposures were seen showing it in contact with them. The loose material consists chiefly of very red clay containing some chert.

The mine was worked on a small scale a number of years ago, the ore having been hauled out in wagons. No operations are being carried on at present, and have not been for some time. The work done was confined largely to prospecting. Developments consist of quite a number of test pits, small open cuts, and a few narrow trenches. All of these are shallow, and afford no reliable basis for accurately estimating the amount of ore remaining in the deposits. It is evident, from the size and number of the openings, that only a relatively small percentage of the ore has been removed.

The ore outcrops at intervals over an area of about 40 acres, and is composed of bowlders, and smaller fragments. The clay soil in places is very red, and is often quite rich with shot ore. The ore is a good grade of dark brown to nearly black limonite.

Digitized by Google

DUBOWICH BANK.

(No. 20, Lewis County map.
Owned by L. Dubowich, Memphis, Tennessee.)

This bank, located 1¼ miles south of Napier, is situated on the top and slopes of secondary ridges and their spurs. Most of the bank is in Lawrence County, but it extends east into Lewis County.

Here the elevation of the ridges is apparently the same as the Napier Mine. The tops of the ridges are between 200 and 250 feet above Chief Creek, and 50 feet above the bottom of the main hollow located near the center of the deposits. No outcrops of rocks occur in the vicinity of the bank. Erosion seems to have been less active on these ridges than on those of the Napier mine, so that the overburden appears to be thicker.

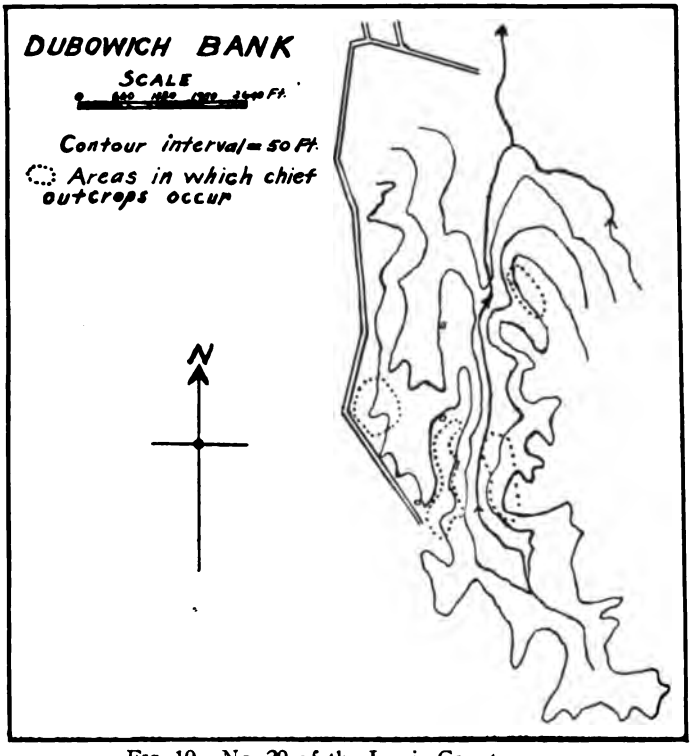


FIG. 10. No. 20 of the Lewis County map.

The developments consist of 18 very shallow test pits distributed in groups over a tract of 80 acres. These pits have been dug on the slopes of the ridges within the areas of the outcrops, and to an average depth of 2¾ feet. Fourteen pits show ore, 7 making an excellent showing, and 4 are blank. Most of the pits are less than 20 feet below the crests of the ridges. The material in which the ore occurs is mainly clay, often of red color, and contains angular chert and some water-worn quartz and chert gravel. The ore outcrops at intervals over an area of 30 acres or

Digitized by Google

more, and consists of small fragments and rather large bowlders of limonite embedded in the clay soil, and as float. The distribution and outcrops are indicated on the accompanying topographic sketch.

The surface ore is siliceous, due to inclusions of sand and chert, but a considerable amount of it appears to be of fair quality. The ore occurs in the cellular and compact forms.

These deposits have not been systematically prospected, and such shallow pits as have been dug are of little value in determining the commercial importance of the bank.

THE SMITH PROSPECT.

(*No. 21, Lewis County map.*
Owned by Frank Smith, Pasadena, California.)

This prospect, located 3 miles north of Napier, is situated on the point of a secondary ridge north of Buffalo River. Here the crest of the ridge is between 125 and 150 feet above the river.

One very shallow test pit has been dug on the south slope of the ridge, and this showed a little ore in red clay. Near this point masses of conglomerate and some breccia occur projecting from the side of the ridge, at about 35 feet below its crest. The mass is 20 feet thick and consists of chert and gravel with limonite as a cement. Some large bowlders occur near the base of the ridge, and these evidently broke off from the large mass above. Shot ore is scattered over an area of 12 to 15 acres, and is especially abundant in the vicinity of the massive ore outcrops. This prospect probably lies close to the solid rocks, for a 40-foot section of stratified rocks is exposed on the south slope of the ridge near Buffalo River. A surface sample of the ore analyzed 54.58 per cent. iron; 9.66 per cent. silica; .441 per cent. phosphorus; and .019 per cent. sulphur.

HALE BANK.

(*No. 22, Lewis County map.*
Owned by John W. Hale, Napier, Tennessee.)

This bank, located 2½ miles north, 35 degrees east of Napier, is situated on and near the top of a secondary ridge and its spurs. This ridge is approximately 250 feet above Buffalo River and on the north side of the river.

Developments consist of 6 test pits varying in depth from 2 to 5½ feet, and all show ore in very red clay. Five of the holes make a good showing for shallow pits, but the sixth shows only a little shot ore. Ore outcrops at intervals over an area of about 8 acres, and the pits have been dug within the area of the outcrop. The pits are near and on the top of the ridge and are scattered over an area of 2 acres. Residual ore outcrops 20 feet below the top of the ridge, so that the ore evidently extends to at least that depth. The ore occurs in the cellular and compact forms, and most of it is of good quality.

Digitized by Google

GRINDERS CREEK DEPOSITS.

The Grinders Creek deposits, located in the south and southeast portion of the county, are situated in the vicinity of Grinders Creek and tributary branches. The topographic sketch below shows part of the Grinders Creek deposits.

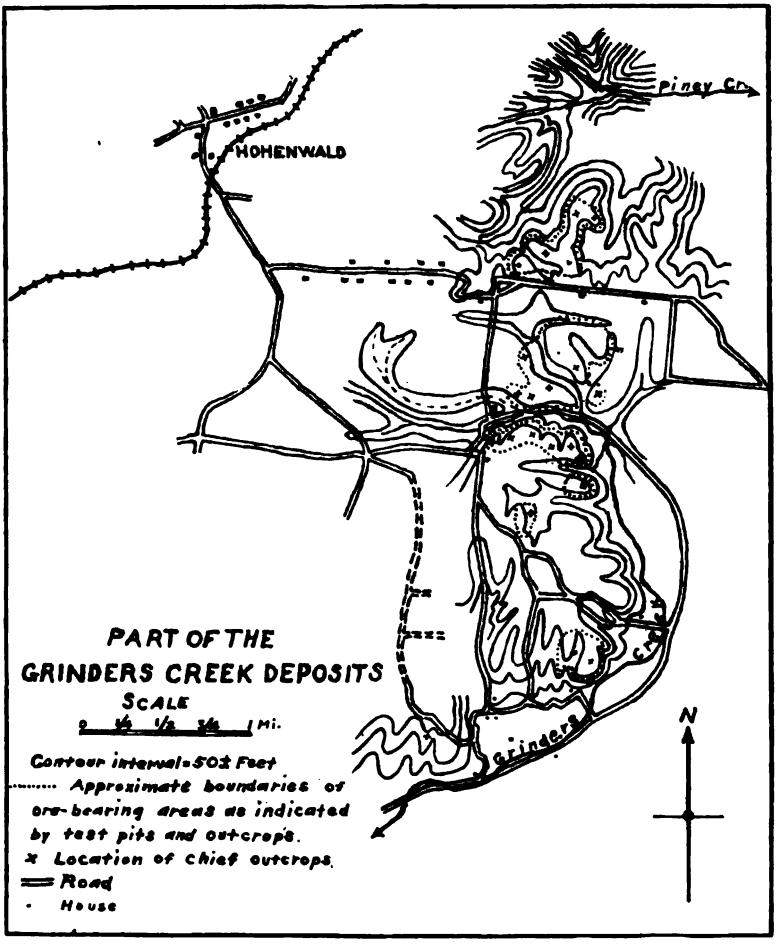


FIG. 11.

LOVELESS AND OVERBEY TRACT.

(No. 23, Lewis County map.
Owned by C. D. Loveless and J. Overbey, Hohenwald, Tennessee.)

This tract is located 2½ miles south, 70 degrees east of the Hohenwald post-office. It is situated on the slopes and crest of a relatively narrow part of the broad ridge that runs through the county from southeast to northwest. The ridge has an elevation of between 1000 and 1050 feet above sea level. This tract of land contains

Digitized by Google

625 acres, but probably less than 150 acres are known to be ore-bearing. Additional prospecting will doubtless extend this area, for many test pits show ore where there are no apparent surface indications.

Iron ore is exposed on the slopes and around the heads of the hollows and shallow draws, and in other favorable situations where the soil has been largely removed by wash. The locations of the most conspicuous outcrops are shown on the accompanying topographic sketch. The deposits, like the others of this region, are pockety, and occur in the loose material overlying cherty limestones of the St. Louis formation. No exposures of bedded rocks were found in the immediate vicinity of the bank, but stratified rocks outcrop 150 feet below the crest of the ridges, in the deep canyons to the north. The bedded rocks have apparently a nearly horizontal structure. The material in which the deposits occur is chiefly very red clay which contains more or less partly weathered angular chert, frequently water-worn quartz and chert gravels, and sometimes sand. The percentage of angular chert varies greatly, and often the material is largely very red clay. Some of the pits show considerable angular chert with little or no gravel, or the reverse in a few instances. The loose material seems to be thick, possibly 100 feet or even more.

Between 55 and 60 test pits have been dug on the slopes and crest of the ridge, and these are scattered in groups over an area of 300 acres. The pits are of varying depth, usually shallow, 3½ to 5½ feet, though quite a number are 10 to 18 feet deep. Twenty-seven pits make a very poor showing of ore or are blank, 15 show ore in fair quantity, and 15 make an excellent showing. The shallow pits on the slopes of the ridge sometimes show a large quantity of ore, but those on the top of the ridge do not, as a rule, show much. Some of the deep holes on or near the crest of the ridge show a large amount of ore. A few pits have been dug on the ridge at 40 feet or more below its crest, and some of these make a good showing.

Limonite is known to outcrop at intervals over an area of about 350 acres. Many of these isolated outcrops are small, and frequently consist entirely of only a sprinkling of shot ore; but others of the exposures are large, and extend over an area of several acres. Isolated fragments may occasionally be found over a rather extensive area. The outcrops consist of bowlders, lumps, and large and small fragments. These are scattered over the surface or are embedded in the clay soil. Sometimes these are thickly strewn over the ground, and then again only an occasional bowlder or fragment occurs. Residual ore was found more than 40 feet below the crest of the ridge. This tract is covered by a rather thick soil blanket, so that outcrops of ore do not occur except in favorable situations. It appears that the overburden may be great in portions of the bank.

The ore is a brown to dark brown or nearly black limonite, and much of it is excellent quality, though highly siliceous ore is occasionally met with. The chief siliceous impurity in the ore is chert, which occurs as inclusions, though sand and quartz are sometimes present in small quantities. A considerable amount of the ore is cellular or honey-combed. There is also a large amount of pots and ore in the compact form.

The writer believes, from a careful examination of the property, that the bank will warrant thorough prospecting, and possibly development. The depth to which the ore extends is not known, but the residual outcrops and the depth of the present test pits indicate that the deposits extend to a greater depth than 35 or 40 feet. Surface showings also occur on lands adjoining the Loveless and Overbey tract,

Digitized by Google

and are especially favorable on those south and southeast of this bank. An average sample of the ore taken from several pits analyzed 49.53 per cent. iron; 13.43 per cent. silica; .743 per cent. phosphorus; and .042 per cent. sulphur.

WAPF BANK.

(No. 24, Lewis County map.
Owned by H. Wapf, Hohenwald, Tennessee.)

This bank is 2¼ miles south, 50 degrees east of the Hohenwald post-office and adjoins the Loveless and Overbey tract on the north. It is situated on the spurs of a ridge, whose elevation is about 1000 feet above sea level. The crests of the spurs are 60 to 70 feet higher than the west fork of Grinders Creek.

The outcrop covers an area of 10 or 12 acres, and within this area large and small bowlders and many small fragments of limonite are more or less thickly strewn over the surface. Most of the large bowlders and many of the small fragments are partly buried in the clay soil. Some of the large chunks are over 3½ feet in diameter. Three shallow test pits were dug on one of the spurs, but most of the material removed has now been put back into the holes. The material remaining around these partly filled pits is mostly very red clay containing shot ore and small lumps of ore.

No outcrops of bedded rocks occur, and the loose material overlying stratified rocks probably has a considerable thickness. The top of the ore deposits seems to be near the surface so that the overburden should not be great. The maximum depth of the deposits, as disclosed by the outcrops, is 25 feet, but the actual depth is not known. Surface indications are exceptionally favorable on 8 or 10 acres of the Wapf property. Surface showings also extend over into the adjoining Smith property, which is described elsewhere.

Most of the ore seems of good quality, but many of the bowlders, particularly the large ones, contain considerable chert. The ore occurs in the compact and cellular forms. The pot ore and many of the solid chunks seem very pure. A representative surface sample analyzed 47.14 per cent. iron; 19.03 per cent. silica; .338 per cent, phosphorus; and .017 per cent. sulphur.

SMITH BANK NO. 3.

(No. 25, Lewis County map.
Owned by Frank Smith, Pasadena, California.)

This bank, located 3 miles south, 53 degrees east of the postoffice at Hohenwald, lies just east of the Wapf bank, on spurs of the same ridge, and may be considered as a continuation of those deposits.

Limonite outcrops at intervals over an area of 25 or 30 acres, and is especially abundant around the heads of the draws and on the points and steep slopes of the spurs. The outcrops consist of fragments, both large and small, embedded in the clay and scattered over the surface. Some masses occur protruding through the clay on the slopes to the draws. Portions of the area show little or no ore, but on other parts the ground is pretty well covered with small pieces of ore.

This locality should be thoroughly prospected. The ore appears to be of about the same character as that occurring in the Wapf bank.

Digitized by Google

SMITH AND ADJOINING PROPERTY.

(No. 26, Lewis County map.
Owned by Frank Smith and others, Pasadena, California.)

The property is south of Smith bank No. 3, and is separated from the latter by an east and west hollow, which is about a half mile in length. It is located 3½ miles south, 52 degrees east of Hohenwald.

Two rather conspicuous outcrops of limonite were found. One of these is situated on the point of a long, narrow ridge, just across the hollow from Smith bank No. 3. The other exposure is ⅖ of a mile south, 64 degrees west of the first mentioned. This outcrop occurs on the east slope to a shallow draw, and consists principally of bowlders embedded in the soil. Both outcrops extend over several acres.

OLD MAYS PLACE (HUGHES BANK).

(No. 27, Lewis County map.
Owned by G. T. Hughes, Jr., Columbia, Tennessee.)

The bank on the "Old Mays Place", located 4¼ miles south, 45 degrees east of the post-office at Hohenwald, is situated in an old field on a secondary ridge and its spurs. The crest of the ridge is about 140 feet above Grinders Creek, and has an elevation of approximately 950 feet above sea level. The slope is to the south, and the bank is on this slope. The surface showings consist almost entirely of small fragments of ore which are very abundant in places. These are scattered over an area of 25 acres or more.

The soil has a red cast, and at certain places the red color is particularly noticeable. The residuum in which the ore occurs is composed largely of very red clay, though a comparatively small amount of angular chert and sometimes a little water-worn gravel is present. No outcrops of bedded rocks were seen, and the indications are that the residuum is thick.

The bank has been developed by 14 test pits distributed over an area of 25 acres. Six that are less than 4 feet deep show a very little ore. Three holes with an average depth of 11 feet, show a fair quantity of ore, and 5 which are 5 to 15 feet deep show a large amount. The pits have been dug from 30 to 50 feet below the crest of the ridge, and the clay from them is often rich with shot ore. The ore is of excellent quality, and this bank will warrant further prospecting. It is a dark brown limonite and occurs in the form of pots and the compact types. Very little chert and practically no sand are associated with the ore. A sample obtained from 5 pits analyzed 55.69 per cent. iron; 3.97 per cent silica; .380 per cent. phosphorus; and .03 per cent. sulphur.

OVERBEY PROSPECT.

(No. 28, Lewis County map.
Owned by J. D. Overbey & Company, Hohenwald, Tennessee.)

This prospect is located 3¾ miles south, 43 degrees east of the post-office at Hohenwald, and ¾ mile northwest of the bank on the "Old Mays Place", described above. Residual iron ore occurs around the head of a very shallow draw on the west slope of a secondary ridge. The draw opens into a north-south hollow, through which flows a small stream, 50 feet below the outcrop. The outcrop covers ¼ of an acre, and is composed of rather large chunks and small pieces of limonite. A sprinkling of shot ore occurs over several acres.

Digitized by Google

MORTON'S AND ADJACENT PROPERTY.

(No. 29, Lewis County map.
Owned by S. D. Morton and others, Hohenwald, Tennessee.)

This property is located 4¼ miles south, 35 degrees east of the post-office at Hohenwald, and ½ mile northwest of Morton's house. The surface showings consist of an occasional bowlder and a few fragments of limonite sparingly distributed over the slopes of several spurs of a ridge and around the heads of several hollows. Some of the ore seen was of excellent quality, especially the pot ore. Most of the ore found was in old fields. A sample of float ore analyzed 56.36 per cent. iron; 5.42 per cent. silica; .749 per cent. phosphorus; and .054 per cent. sulphur.

CHRISTIAN BANK NO. 1.

(No. 30, Lewis County map.
Owned by H. T. Christian, Riverside, Tennessee.)

This deposit, located 3½ miles south, 12 degrees east of the post-office at Hohenwald, is situated on the south slope to a shallow hollow, on the spur of a ridge near its crest. It is near the head of Rush Branch, and about 2 miles northwest of its mouth.

The outcrop covers an area of nearly an acre. It consists of bowlders protruding through the clay soil and of small fragments scattered over the surface. Three shallow pits, ranging from 3 to 4 feet in depth, have been dug within the area of the outcrop. Two pits are on the slope of the spur, and the other one is in the hollow near its base. All the pits show some ore, and one a considerable quantity. The last clay thrown out of the two upper pits is very red. The ore is a fair quality of limonite.

A small outcrop of iron ore was found on Mr. Brown's land, ½ mile north of here.

CHRISTIAN BANK NO. 2.

(No. 31, Lewis County map.
Owned by H. T. Christian, Riverside, Tennessee.)

This bank is one mile north, 38 degrees west of the junction of Grinders Creek and Buffalo River. The deposits are situated on the top and slopes of a high southeast spur of a secondary ridge. The ridge has an elevation of 900 feet above sea level, and its crest is nearly 200 feet above Grinders Creek.

The deposits occur in red clay with which is associated more or less angular chert and sometimes water-worn gravel. Bedded rocks are exposed on the northeast and east slope of the ridge near its base. A 40-foot section of cherty limestones was observed near the mouth of Rush Branch. As the top of this section is approximately 125 feet below the crest of the ridge, it appears that the detritus overlying solid rock is quite thick.

The outcrop extends over an area of 12 to 15 acres. It is composed of bowlders and fragments embedded in the soil and scattered over the surface. On a large part of this area, especially on that south of the road, the ground is thickly strewn with ore. There are bowlders over 5 feet in diameter, some of which appear heavy with iron, but others are light and contain a large per cent. of chert. A mass of highly siliceous ore extends along the south face of the spur for a distance of 75 feet, about 40 feet below its crest. Twenty shallow test pits have been dug within

Digitized by Google

the area of the outcrop. Eight are located on the north side of the road, and 12 on the south side. Six of those on the north side of the road are nearly blank, and the 2 remaining ones make a fair showing. Of the 12 pits on the south side of the road 7 show very little ore, 4 make a fair showing, and one an excellent showing. The last material removed from the pits is generally of a deep red color, but some of the very shallow ones do not show any very red clay. This material often has a large quantity of shot ore mixed with it, and angular chert is frequently abundant, but comparatively little water-worn gravel was noticed.

Much of the ore is siliceous, silica occurring principally as embedded chert and sometimes in the form of sand; but the percentage of siliceous material varies largely, portions of the ore being almost free from it, while the amount in other portions runs very high. The ore occurs in both the cellular and compact forms. Relatively little pot ore was seen, and most of it being of the solid chunk variety. Some limonite cemented sandstone was observed. A representative sample taken from the dumps analyzed 46.73 per cent. iron; 20.79 per cent. silica; .476 per cent. phosphorus; and .094 per cent. sulphur.

The test pits and surface showings indicate that deposits of ore occur over an area of at least 10 or 12 acres. The depth to which the ore extends is not known, but the residual outcrops 40 feet below the crest of the spur indicate that ore extends to at least that depth.

CHRISTIAN FLOYD AND ADJOINING PROPERTY.

(No. 32, Lewis County map.
Owned by H. T. Christian, Henry M. Floyd, C. R. Brown and others, Hohenwald, Tennessee.)

That part of the property showing ore is practically a continuation of the Christian Bank No. 2, already described, and is located on a northeast spur of the same ridge.

In the road on the northeast slope of the spur, there are some spots that have a very red clay soil. Shot ore is abundant in the clay, and a few hundred feet north of this place lumps of siliceous ore are distributed over the surface and protrude through the clay of the road. Similar indications occur sparingly around the heads of several draws on this spur.

CHRISTIAN BANK NO. 3.

(No. 33, Lewis County map.
Owned by H. T. Christian, Riverside, Tennessee.)

This bank is located 2⅗ miles north, 45 degrees east of Riverside, or 1½ miles east of Nancy. It is situated on the top of a ridge, at an elevation of 900 feet above sea level. On and near the point of a northeast spur of the ridge 11 test pits have been dug. Their depth varies from 2 to 3½ feet, which is entirely too shallow for test purposes. Only 2 of the 11 holes showed a fair quantity of ore, and most of the others are blank or nearly so. Seven holes were found on the southeast extension of the main ridge, and between this place and the one previously described, 5 more pits occur. These pits are also very shallow, for their average depth is only about 3 feet. Six make a fair to excellent showing of ore, and 1 a poor showing. Some of the 5 remaining ones show more or less shot ore, and others are blank. The surface showings at this place extend over 8 to 10 acres.

Digitized by Google

The outcrops extend over a total area of possibly 10 or 20 acres and at certain places, the surface is thickly strewn with large and small fragments of limonite. Some of these are buried in the clay soil, while others are loosely distributed over the ground. A few of the bowlders are more than 2 feet in diameter, but large chunks of ore are rare. The outcrops consists mostly of shot ore. Some of the root-wads show a large quantity of ore. No exposures of stratified rock were found in the vicinity of the bank.

The ore occurs in red clay containing chert fragments, which are often very abundant. The surface showings between the two main outcrops and the few shallow pits, indicate that ore would probably be encountered by sinking deep shafts on the higher lands located on and near the crest of the ridge.

Much of the ore seems free of excessive chert, gravel, and sand, but some is quite siliceous. The ore is found in both the cellular and compact forms. An average sample from 11 shallow pits analyzed 51.94 per cent. iron; 12.45 per cent. silica; 1.233 per cent. phosphorus; and .045 per cent. sulphur.

CANE CREEK DISTRICT.

The Cane Creek district is in the northwestern part of the county. The following is a description of the deposits occurring in it:

SKELTON BANK.

(*No. 34, Lewis County map.*
Owned by John Skelton and others, Hohenwald, Tennessee.)

This bank, located 4 miles north, 40 degrees west of Hohenwald, is situated on the spur of a ridge near Cotton Branch, about 125 feet above that stream.

A 15-foot excavation has been made into the south face of the spur, 45 feet below its crest. A large quantity of bowlder pipe and needle ore was encountered. Some of the bowlders are over 3 feet in diameter and are heavy with iron. Part of the ore in the excavation has the appearance of irregular, thin veins in the clay. Ore outcrops over an area of about 1½ acres. Fragments of leached and porous chert, often stained with iron oxide, are abundant on the top and slopes of the ridge. The ore is of excellent quality, but probably does not occur in workable quantity. The locality has never been thoroughly prospected.

A typical sample of the ore analyzed 48.24 per cent. iron; 21.10 per cent. silica; .702 per cent. phosphorus; and .083 per cent. sulphur.

PROSPECT NORTHWEST OF THE SKELTON BANK.

(*No. 35, Lewis County map.*)

Three-fourths of a mile north, 25 degrees west of the Skelton bank, there is an outcrop of low grade limonite covering an area of about ½ acre. The outcrop occurs on a spur of the same ridge on which the Skelton bank is located. Most of the ore is massive and highly siliceous, but some of it is of fair quality. Lumps of compact ore are scattered over the ground. The locality has never been systematically prospected.

Digitized by Google

GOODMANS PRONG PROSPECT NO. 1.

(No. 36, Lewis County map.
Owned by West Henson and others, Hohenwald, Tennessee.)

This prospect is on the south side of Goodmans Prong, a branch of Cane Creek, and 1¼ miles south, 35 degrees east of its mouth.

Large bowlders and many small fragments of siliceous limonite outcrop over an area of one acre on the slopes of a very narrow ridge. The ridge is west of the junction of Stillwater Branch, with Goodmans Prong, and the top is approximately 125 feet above the latter stream. The outcrops extend to near the base of the ridge. About 1000 feet east, and on the same ridge, is another small outcrop. The ore at both places is a light brown limonite, and is very cherty. A number of other outcrops have been reported as existing on the ridges only a short distance south and west of this locality.

GOODMANS PRONG PROSPECT NO. 2.

(No. 37, Lewis County map.
Owned by Andrew King, Hohenwald, Tennessee, and the L. P. Cheatham estate.)

This prospect is located 2½ miles north, 60 degrees west of Hohenwald, on the east side of the Goodmans Prong road. It is situated on the top of a ridge, which is a continuation of the broad, flat ridge lands surrounding Hohenwald. The ground is more or less covered with shot ore and a few larger fragments occur. Three very shallow test pits have been dug on the top and slope of the ridge. A large quantity of ore was removed from the pit on the slope of the ridge near the top. The other 2 are on the top of the ridge. One of these shows some very red clay containing shot ore, and the other mostly angular chert gravel and a light-colored clay. The writer found only 3 pits, but several more are said to have been dug in this locality.

It thus appears that the prospecting has not been sufficient to prove the value of the deposits. The ore is evidently hidden or masked by what seems to be a thick overburden. That seen was of good quality, considering it is surface ore. At a greater depth a better quality may probably be found. A representative sample of the surface ore analyzed 57.35 per cent. iron; 4.67 per cent. silica; .847 per cent. phosphorus; and .035 per cent. sulphur.

THE SKELTON PLACE AND VICINITY.

(No. 38, Lewis County map.
Owned by J. E. Morrow, Hohenwald, Tennessee, William Murphy, and others.)

This locality is on the Linden road 3 miles west of Hohenwald, and should be considered as a part of the so-called "flatwoods" country. The indications for iron ore are a very red soil, shot ore, and residual chunks of low grade, highly siliceous, liver-colored conglomerate ore exposed in the road, and around the heads of adjacent hollows. The red clay soil shows up for a distance of 1500 feet along the road, and contains shot ore and occasionally larger fragments. A few test pits were dug a number of years ago, but these are partly filled up. North of the road shot ore is abundant at intervals over an area of several hundred acres, especially

Digitized by Google

on the slopes to the hollows. Root-wads frequently show shot ore. If there is much ore in this vicinity, it is overlaid by a considerable thickness of water-worn quartz and chert gravels, which appear to be over 25 feet thick in places.

FAIN BANK.

(No. 39, Lewis County map.
Owned by J. B. Fain, Hohenwald, Tennessee.)

This bank is located 4¼ miles north, 80 degrees west of the post-office at Hohenwald. It is situated on the crest of several secondary ridges and their spurs, near the head of Fain Prong, which is a branch of Cane Creek. The tops of the ridges are between 125 and 150 feet above Fain Branch. The ridges are very narrow, their crests being in most cases, less than 250 feet wide.

Large and small fragments of ore occur on the top and slopes of the ridges. Some of these are embedded in the clay soil, while others are scattered over the surface. These fragments are most abundant on the points and depressions of the ridges where the soil has been largely removed by wash. Root-wads frequently show shot ore and water-worn gravels. Angular chert and gravel are abundant at many places on these ridges. No outcrops of solid rocks were observed on or near the ridges, but such rocks outcrop in the bed of the streams east and west of here. Surface indications occur at intervals over an area of at least 40 acres and to near the base of some of the ridges. Iron ore outcrops on ridges north of the Fain property, and is reported as occurring at a number of other localities in this neighborhood.

The ore is a light brown limonite, associated with a considerable amount of chert. An average surface sample of the ore analyzed 39.81 per cent. iron; 26.93 per cent. silica; .668 per cent. phosphorus; and .110 per cent. sulphur.

THE TRACE CREEK DEPOSITS.

The Trace Creek deposits, located in the southwest part of the county, are situated in the vicinity of Trace Creek and its tributary streams.

ODOM AND CHEATHAM LANDS NO. 1.

(No. 40, Lewis County map.
Owned by Odom Brothers, Hohenwald, and L. P. Cheatham estate.)

This prospect is located 4¾ miles south, 80 degrees west of the Hohenwald post-office. On a secondary ridge and its spurs, shot ore was found in root-wads and also strewn over the surface. Sometimes these small pieces of ore are very abundant, but usuaully there is only a sprinkling of such. These surface indications extend over an area of 30 acres or more. A short distance northeast of Odom's house, large and small fragments of ore are abundant on the south slope of the ridge, strewn over the surface and protruding through the clay soil. The outcrop extends along the hill for a distance of 150 feet. A shallow excavation was found in the area of the outcrop, and the material removed showed a large quantity of siliceous ore. A surface sample of this ore analyzed 54.9 per cent. iron; 6.97 per cent. silica; 1.189 per cent. phosphorus; and 0.21 per cent. sulphur.

Digitized by Google

ODOM AND CHEATHAM LANDS NO. 2.

(No. 41, Lewis County map.
Owned by Odom Brothers, Hohenwald, Tennessee, and the L. F. Cheatham estate.)

This prospect is 4½ miles south, 75 degrees west of Hohenwald. It is on a ridge about ½ mile southeast from the prospect described in No. 1. Iron ore outcrops around the heads and side slopes to several shallow V-shaped ravines, small fragments of ore are scattered over the points of several spurs of the main ridge, and root-wads frequently show red clay subsoil and some shot ore. Iron ore is reported to outcrop in several other localities in this vicinity, but these were not visited.

The Odom and Cheatham lands have never been systematically prospected, and nothing is known regarding the possibilities of finding ore in paying quantities. Not enough was found to enable the writer to judge of its character, but most of that seen was rather siliceous.

THE CHARLOTTE LUMBER COMPANY TRACT NO. 1.

(No. 42, Lewis County map.
Owned by the Charlotte Lumber Company, Charlotte, Michigan.)

This prospect is located ⅗ of a mile northwest of the junction of Sweetwater Branch with Trace Creek. At this place, compact bowlders of limonite occur in the bottom of a draw between two spurs of a ridge, and on the slopes to the hollow. The ore protruding from the slopes is 15 feet above the bed of a small stream, and is evidently in place. It appears that the stream has cut through an ore pocket. The outcrop is small, but the ridges were covered with leaves at the time the prospect was visited, so that other outcrops could not have been easily seen even if present. There are doubtless other occurrences of ore in this vicinity. The region has never been prospected.

THE CHARLOTTE LUMBER COMPANY TRACT NO. 2.

(No. 43, Lewis County map.
Owned by the Charlotte Lumber Company, Charlotte, Michigan.)

This prospect is 4 miles north, 15 degrees west of Riverside, and ¾ of a mile east of the junction of Sweetwater Branch with Trace Creek. It is situated on the southwest slope and the point of a high secondary ridge. The crest of the ridge is over 250 feet above Trace Creek and has an elevation of between 950 and 1000 feet above sea level.

The principal outcrop consists of compact bowlder ore, embedded in the soil on the southwest slope of the ridge at approximately 30 to 35 feet below the top. This outcrop covers an area of 1 acre. Besides the main outcrop, there are isolated bowlders and small lumps distributed over an area of 6 or 7 acres on and near the point of the ridge. The clay adhering to the roots of several fallen trees contain shot ore and sometimes larger fragments. This ridge seems to be covered by a rather thick soil mantle. The north slope has a deeper soil than the southwest one. Comparatively little angular chert and gravel was noticed on the ridge or in its vicinity.

Digitized by Google

The surface showings are fair over about 4 acres, and there are at least 4 to 6 acres more on which the surface indications are more or less favorable, thus making a total of 8 or 10 acres over which pockets of ore may be expected to occur. The ore extends to a depth of at least 30 feet, for it is exposed at that distance below the crest of the ridge. Deep pits are necessary to test the property. Most of the ore is of fair quality, but some of it is very siliceous, due chiefly to chert inclusions. An average sample taken from the outcrop analyzed 50.9 per cent. iron; 10.50 per cent. silica; 1.422 per cent. phosphorus; and .032 per cent. sulphur.

CHARLOTTE LUMBER COMPANY TRACT NO. 3.

(*No. 44, Lewis County map.*
Owned by the Charlotte Lumber Company, Charlotte, Michigan.)

This prospect, located 4¼ miles north, 53 degrees west of Riverside, is situated on and very near the crest of a high, chert-covered, secondary ridge, with an elevation of 900 feet above sea level, and about 250 feet higher than Sweetwater Branch. Large bowlders and many small fragments of iron ore outcrop over an area of several acres around the head of a hollow, near the crest of the ridge. About 1000 feet southwest of this place and on the opposite or south slope of the ridge, near its point, is another small outcrop of the same character of ore. Both outcrops consist of ore embedded in the clay soil and also strewn over the surface. Lumps of ore and shot ore occur sparingly between the two principal exposures. The slopes and top of the ridge are strewn with angular chert fragments, some of which have a fresh appearance. These suggest that bedded rocks of the St. Louis formation are comparatively near the surface, though no outcrops were observed on any of these ridges.

The ore is a light brown limonite and is often quite siliceous. Many of the bowlders contain decomposed chert and some gravel, while others are nearly free of foreign material. This locality has never been systematically prospected, and there are probably other iron ore outcrops in this vicinity. A representative sample taken from the outcrop analyzed 54.11 per cent. iron; 8.99 per cent. silica; .732 per cent. phosphorus; and .044 per cent. sulphur.

CHARLOTTE LUMBER COMPANY TRACT NO. 4.

(*No. 45, Lewis County map.*
Owned by the Charlotte Lumber Company, Charlotte, Michigan.)

This outcrop of ore is in the extreme southwest corner of Lewis County, 6½ miles north, 60 degrees west of Riverside. The ore exposure is on the point of a spur of a secondary ridge, and covers an area of about 300 square yards. It consists of large and small chunks embedded in the soil, and float ore. Most of it is very cherty. A surface sample taken from the outcrop analyzed 34.64 per cent. iron; 35.02 per cent. silica; .688 per cent. phosphorus; and .048 per cent. sulphur.

CHARLOTTE LUMBER COMPANY TRACT NO. 5.

(*No. 46, Lewis County map.*
Owned by the Charlotte Lumber Company, Charlotte, Michigan.)

These iron ore outcrops are located 4 miles north, 80 degrees west of the junction of Sweetwater Branch with Trace Creek. They are situated on the spurs of ridges at less than 100 feet below their crests.

Digitized by Google

The outcrops consist of bowlders and large and small fragments, protruding through the clay soil on the slopes of the spurs, and also scattered over the surface. The outcrops are distributed over an area of 80 acres. Much of the ore is cherty, but some of good quality was seen. The siliceous outcrops may give place to ore of better quality with depth. An average sample taken from the outcrop analyzed 40.44 per cent. iron; 26.97 per cent. silica; .278 per cent. phosphorus; and .009 per cent. sulphur.

JACKS BRANCH-ROCKHOUSE CREEK GROUP.

The Jacks Branch-Rockhouse Creek group, located in the southern portion of the county, is situated on a high ridge and its spurs, between Jacks Branch and Rockhouse Creek. It has a north and south trend and an elevation ranging between 900 and 1000 feet above sea level, the crest being 200 to 250 feet higher than Jacks Branch.

The ore is found in pockets in the clay, gravel, chert, and other loose material overlying the St. Louis formation. No outcrops of bedded rocks were seen in the immediate vicinity of the banks, but such rocks are exposed on the lower slopes of the ridge. The loose material is probably thick. Water-worn quartz and chert gravels are more or less abundant on the top of the main ridge and its spurs, especially on the main ridge, where these gravels in places, appear to have a thickness of over 15 feet. Most of the outcrops occur on the spurs. Nearly all the test pits are very shallow, and afford little knowledge regarding the size and depth of the deposits. The topographic sketch shows a part of the Jacks Branch-Rockhouse Creek group.

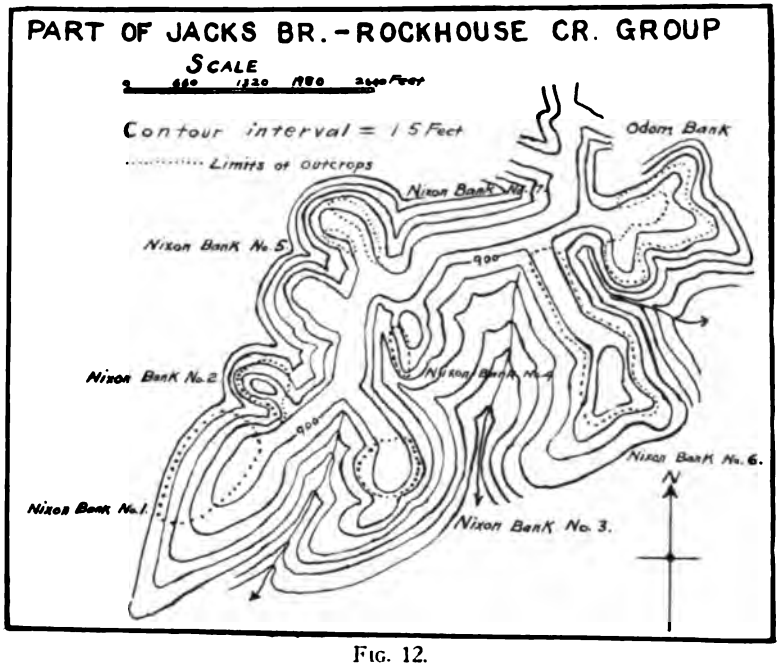


FIG. 12.

Digitized by Google

NIXON BANK NO. 1.

(No. 47, Lewis County map.
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

This bank is on the southwest spur of the ridge, near Jacks Branch, and ⅘ of a mile north, 8 degrees east of McLean. Residual ore occurs over an area of 8 to 10 acres. Massive ore and bowlders protrude through the clay on the west slope of the ridge, and some of these occur more than 30 feet below the top.

Fifteen pits have been sunk on the top and slopes of the spurs, and these are distributed over an area of about 5 acres. Some have been dug where there is apparently little or no surface showings. The pits range from 2 to 30 feet in depth. About 25 per cent. of them make an excellent showing of ore, 50 per cent. a poor to fair showing, and 25 per cent. are blank. The clay in most of the pits is very red, and is sometimes rich with shot ore. The material from the pits is composed mainly of clay which contains some angular chert, and frequently water-worn gravel.

The test pits and outcrops indicate that at least ten acres are ore-bearing, and that the ore extends to a depth of 30 feet or more. It often shows particles of chert and frequently grains of sand, but much of the limonite is of good quality. The ore occurs in the compact forms and as pots. A representative sample analyzed 47.07 per cent. iron; 18.42 per cent. silica; .640 per cent. phosphorus; and .042 per cent. sulphur.

NIXON BANK NO. 2.

(No. 48, Lewis County map.
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

This outcrop is situated on a spur a short distance north of and adjoining the Nixon Bank No. 1. The outcrop consists of a few fragments and small bowlders scattered over perhaps two acres, and the ore seems to be of about the same character as that occurring in the Nixon Bank No. 1.

NIXON BANK NO. 3.

(No. 49, Lewis County map.
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

This bank, located 1 mile north, 30 degrees east of McLean, is situated on a south spur of the main ridge. The outcrop consists of small fragments, and an occasional bowlder of brown ore over a nearly circular area of 4 or 5 acres. It has been prospected by 4 pits ranging from 2 to 10 feet in depth. The pits are about 140 feet apart, and occur at different elevations on the spur. All show more or less ore in red clay. Three others have been sunk on a narrow part of the spur, northwest of this outcrop, near the main ridge. These are shallow, and show chiefly water-worn gravel and angular chert.

The ore is a light to dark-brown limonite and frequently contains some fine sand and small, irregular flakes of decomposed chert, but, on the whole, seems free of excessive siliceous impurities. It is of both the cellular and compact types. A typical sample analyzed 50.41 per cent. iron; 13.49 per cent. silica; .320 per cent. phosphorus; and .049 per cent sulphur.

Digitized by Google

NIXON BANK NO. 4.

(*No.* 50, *Lewis County map.*
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

The outcrop is situated on a south spur of the ridge about 1000 feet north of the Nixon Bank No. 2. At this place residual limonite is exposed at intervals over an area of 2 acres.

NIXON BANK NO. 5.

(*No.* 51, *Lewis County map.*
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

The outcrop is about 900 feet northwest of Nixon Bank No. 4, and is situated on a north spur of the ridge opposite the latter bank. At this location residual brown ore occurs sparingly over an area of 5 acres.

NIXON BANK NO. 6.

(*No.* 52, *Lewis County map.*
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

This band is 1⅕ miles north, 35 degrees east of McLean, and is on the southeast spur of the main ridge. Outcrops extend over an area of approximately 17 acres, parts of which are thickly covered with fragments of brown ore, but in most places, the showing consists of only a few scattered fragments. Some bowlders 2 feet in diameter were found on the point of the spur. Many of the large fragments and most of the bowlders are embedded in the soil.

The ore is light to dark-brown in color and varies in texture from compact to cellular. Silica is present chiefly in the form of small particles, and these inclusions frequently have a flaky aspect. A surface sample analyzed 53.69 per cent. iron; 9.10 per cent. silica; .352 per cent. phosphorus; and .002 per cent. sulphur.

NIXON BANK NO. 7.

(*No.* 53, *Lewis County map.*)

On the main ridge northwest of the above described outcrop about 25 very shallow test pits were found. They occur at different elevations on the ridge, but most of them are on the slopes less than 30 feet below the crest. These pits vary from 2 to 4 feet in depth, and only a few showed any ore, but this is to be expected from the shallowness of the pits. The material taken out is mainly clay, which contains an abundance of water-worn quartz and chert gravels and more or less angular chert fragments. It thus appears that there is a considerable thickness of gravel on top of the ridge at this place. This locality is west of and between the spurs where the outcrops of previously described banks occur, but here the exposures consist of only an occasional fragment, and some shot ore. The pits are scattered over an area of 25 acres, and have been dug where there are little or no surface indications. The ore seen was a light-brown or liver-colored limonite, and generally highly siliceous, though the quality might improve with depth.

On the main ridge, about ⅗ of a mile north of this place, 20 or more pits were found on both sides of the road. This locality is between the Grinder and Odom banks. These pits are also very shallow. A few showed a little ore, but most of them are blank, as would be expected from their small depth. They have been dug

Digitized by Google

where there are little or no surface showings, but residual ore outcrops around the heads of several hollows in the immediate vicinity. The pits usually show a large amount of water-worn gravel and some angular chert in the clay. A part of this locality is described under the Nixon Bank No. 7, which adjoins it.

From the preceding statements it is quite evident that if ore in quantity exists at either of these localities, deep shafts will have to be sunk to find it. The detritus overlying solid rocks is probably thick, and outcrops of bedded rocks do not occur in the immediate vicinity.

ODOM BANK.

(No. 54, Lewis County map.
Owned by Dempse Odom, Hohenwald, Tennessee.)

This bank, located 1⅖ miles north, 28 degrees east of McLean, is situated on an east spur of the main ridge, as shown on the topographic sketch above. The bank is marked by an outcrop of limonite in the form of a few bowlders, lumps, and small fragments occurring here and there over an area of 8 to 10 acres. Some of the ore is embedded in the clay, but most of the exposures are loose residual fragments. The ore is quite abundant on portions of the south and southeast slopes of the spur, near its point.

A mining company is reported to have offered to prospect the bank, but as yet no test pits have been dug. The value of the property can not even be approximately determined from the surface showings alone, which extend west into the Nixon property.

The ore is a light- to dark-brown limonite, which has a texture varying from closely compact to coarsely cellular. The ore is frequently somewhat siliceous, which is chiefly due to embedded chert, for very little sand and quartz were visible in any of the specimens examined. An average surface sample of the ore analyzed 48.50 per cent. iron; 14.38 per cent. silica; 1.071 per cent. phosphorus; and .029 per cent. sulphur.

NIXON BANK NO. 8.

(No. 55, Lewis County map.
Owned by the Henry Nixon heirs, Centerville, Tennessee.)

This bank is located 1¾ miles north of McLean and 1¼ miles northwest of Grinders mill. It is on and near the crests of the main ridge and several of its secondary ridges and their spurs.

Iron ore, in the form of bowlders and fragments embedded in the clay soil and scattered over the surface, is exposed at intervals over an area of 450 acres, within which the test pits have been dug. The outcrops cover an area varying from a few square yards to several acres, and are most abundant on the points and slopes of the ridges and spurs were the soil has been largely removed by wash. Residual ore was found in the bottoms of several of the shallow hollows, on the lower slopes of some of the ridges and in shallow pits, more than 60 feet below the crest of the main ridge. An occasional lump of ore and shot ore can be found over nearly the entire tract.

Developments consist of more than 66 test pits scattered in groups over the area. These range from 2 to 7 feet in depth. As a rule, the holes have been dug where the surface showings are most abundant. Thirty-eight pits show more or less ore and 28 are blank or show only a little shot ore. Nine of the 38 show a large amount of ore, 21 fair quantity, and 8 make a poor showing. The blank holes are on or

Digitized by Google

very near the top of the ridges, and the material removed from these is mainly water-worn and a light colored clay often containing angular chert fragments. The material is frequently nearly all gravel, thus suggesting that, at least on the crest of the ridges, a rather thick blanket of gravel overlies the ore deposits. The last material removed from those pits that show ore consists of red clay, angular chert, and sometimes water-worn gravel.

The ore has a dense to coarsely cellular texture, but usually occurs in the compact form. The color of the limonite varies from light-brown or liver color to dark-brown or nearly black, on fresh surfaces. It is siliceous, and some of it highly so. The chief siliceous impurity is decomposed white chert which occurs in the form of small fragments and flaky particles incorporated with the ore. Small grains of sand are sometimes present, but large amounts of sand and quartz were not often noticed in any of the ore examined. Some of the dark-brown ore is nearly free of silica, and this is evidently of excellent quality. The quality may improve with depth. A representative sample taken off the dumps of the 38 pits analyzed 43.84 per cent. iron; 20.42 per cent. silica; .822 per cent. phosphorus; and .05 per cent. sulphur.

A close examination of this bank warrants the conclusion that many deep shafts will have to be sunk before any opinion can be formed regarding the value of the property. The prospecting already done is superficial and of little value. However, the test pits and outcrops indicate that deposits of ore doubtless exists over a large portion of the area, and to a depth of perhaps 60 feet. No outcrops of bedded rocks were seen, and the residuum may be quite thick.

GRINDERS BANK.

(No. 56, Lewis County map.
Owned by J. C. Grinder, Hohenwald, Tennessee.

This bank is located 1⅘ miles north, 25 degrees east of McLean, and is on an east spur of the main ridge. The elevation of the spur ranges from 950 to nearly 1000 feet above sea level, and its crest is over 200 feet higher than Grinders Creek.

Rocks are exposed in the bed of a small stream on the south slope of the spur, near its base, and about 150 feet below its crest. The loose material evidently extends to a considerable depth, on the crest of the spur. Residual iron ore occurs on portions of 10 or 12 acres. The showing consists of bowlders, lumps, and small fragments, the best ones being on the point and south and east slopes of the spur.

The bank has been prospected by nearly 40 test pits, which are scattered over an area of 8 acres. Most of the pits range from 3 to 12 feet in depth, and a few are 15 feet deep. The pits occur at different elevations, but most of them are on the south slope and point of the spur at less than 30 feet below the top. One deep shaft (partly filled with water at the time visited) is reported to show ore at the bottom, and to have encountered some ore throughout the greater portion of its depth of 47 feet. About 40 per cent. of the pits show a fair to large quantity of ore, 35 per cent. make a poor showing, and 25 per cent. are blank or nearly so. The pits that are nearly blank show only a little shot ore. The ore occurs in very red clay. Angular chert and sometimes water-worn gravels occur in the clay.

Much of the ore is a dark-brown limonite of apparently good quality, for excessive amounts of siliceous matter is not visible in most of this ore. However, some of it is siliceous, which is due chiefly to embedded chert, although sand and small chert pebbles occur. The ore occurs mostly in the compact forms, but pots and other types are met with.

Digitized by Google

This bank deserves systematic prospecting and possibly development. It extends over into the adjoining Nixon property, but nearly all the pits have been put down on that part of the spur owned by J. C. Grinder. More and deeper pits should be dug, and these should be more evenly distributed. Other portions of the spur should be thoroughly prospected. An average sample taken from several pits analyzed 50.46 per cent. iron; 12.39 per cent. silica; .841 per cent. phosphorus; and .221 per cent. sulphur.

BARKER TRACT.

(*No. 57, Lewis County map.*
Owned by J. M. Barker, Bristol, Tennessee.)

The part of the tract showing iron lies 1½ miles south, 10 degrees west of Shubert. Here small outcrops of iron ore occur around the heads of several hollows, and a few fragments of high grade ore were found on the points of several spurs of the main ridge. Such surface showings occur sparingly over several hundred acres of the Barker land south and southwest of the above described location. Some of the ore seen was highly siliceous. There is a sprinkling of shot ore over a rather extensive territory.

(*No. 57a, Lewis County map.*)

On the point of a long, narrow spur north of the Grinder Bank, there is a small outcrop of limonite covering several square yards. The top of the spur is covered by a water-worn gravel deposit of considerable thickness, and no other exposures were found. Brown ore is reported to outcrop on other spurs north of this place. This tract has not been prospected.

ROCKHOUSE CREEK DEPOSITS.

The Rockhouse Creek deposits are located in the southern part of the county. Only a few isolated deposits of iron ore situated in the vicinity of Rockhouse Creek and its branches will be described under this heading, for most of the banks have already been described under the Jacks Branch-Rockhouse Creek group.

CARTER'S LAND.

(*No. 58, Lewis County map.*
Owned by J. C. Carter, Hohenwald, Tennessee.)

This property is 1½ miles west of Hohenwald. A small stream runs through the center of the property from northwest to southeast. The crest of the ridges on both sides of the stream are 60 to 70 feet above the bed of the stream. The surface showings occur on several spurs of the broad ridge on which Hohenwald is located. Small compact chunks of ore were found, which seemed heavy with iron. On top of the spur there is an outcrop of residual ore over an area of ⅕ of an acre. Shot ore and a few larger fragments occur on several spurs a short distance southeast and west of here, and are particularly abundant on the spur located 500 feet to the southeast.

NIXON AND CRAIG BANK.

(*No. 59, Lewis County map.*
Owned by the Henry Nixon heirs, Centerville, Tennessee, and Mrs. H. Craig, Riverside, Tennessee.)

This bank, located ⅗ of a mile north, 30 degrees west of Nancy, is situated on and near the top of a southeast spur of a main ridge. The spur has an elevation of

Digitized by Google

between 900 and 950 feet above sea level, and its crest is nearly 250 feet higher than Rockhouse Creek. The main ridge has a north and south trend, and its elevation ranges from 900 to 1000 feet above sea level. No exposures of bedded rock occur, and the detritus overlying solid rock is probably thick on the crest of the spur and the main ridge.

The outcrop consists of small fragments and a few bowlders of brown ore scattered in patches over an area of about 8 acres. These are very abundant on a portion of the Craig property, and occur around the head of a draw. Ten shallow test pits have been dug on the crest of the spur, distributed over an area of 5 or 6 acres. The pits vary in depth from 2 to 6 feet. Six of the 10 pits show a poor to fair quantity of ore, and the 4 remaining holes are blank. The ore occurs in cherty clay, some of which is of a very red color, and frequently is rich with shot ore.

The ore is a light- to dark-brown limonite, which generally occurs in the compact form. Some of it is cherty, but some is of good quality. The prospecting has not been thorough and the acreage of ore-bearing property is not known. An average sample taken from several pits analyzed 51.63 per cent. iron; 10.87 per cent. silica; 1.113 per cent. phosphorus; and .036 per cent. sulphur.

ALLENS CREEK-RIVERSIDE MINING DISTRICT.

The Allens Creek-Riverside Mining District is located in the southern part of Lewis County and the northeastern part of Wayne County. Most of the banks placed in this district are situated in Lewis County, near Riverside, but the Allens Creek Mine and a few other deposits near Allens Creek, although located in Wayne County, will be also described under this heading.

PERCY MINE.

(No. 60, Lewis County map.
Owned by the Warner Iron Company, Nashville, Tennessee.)

This mine, located ⅘ of a mile south, 60 degrees east of Riverside, is situated on and near the crests of a high ridge and its spurs, at an elevation of between 950 and 1000 feet above sea level. The top of the ridge is 250 feet higher than Allens Creek.

A 50- to 60-foot section of cherty limestone outcrops on the lower west slopes of the ridge, near the creek. The deposits are pockety. The pockets vary in size, shape, and are found irregularly distributed through the detritus overlying the St. Louis formation. The loose material probably has a thickness of 100 feet or even more. It is largely composed of very red clay which contains varying quantities of decomposed angular chert and water-worn gravel. Frequently the water-worn gravel is cemented by limonite so as to form a conglomerate. This conglomerate is very abundant in portions of the bank and sometimes seriously interferes with mining operations. The overburden in this mine varies from nothing to more than 15 feet.

The surface showings, as a rule, are not conspicuous, and rich pockets of ore are frequently found where there are no outcrops. Developments consist of a number of irregular open cuts and small pits as shown on the accompanying topographic sketch.

Digitized by Google

The largest cut contains an area of 2½ acres and has a maximum depth of 60 feet in its west end. The other cuts contain a total area of 5½ acres and range in depth from 10 to a maximum of 25 feet. The deposits extend to an unknown depth, the bottom not having been reached at 60 feet. Solid rock has not been encountered in any of the workings. The total area containing ore is not definitely known, for it is often found where there are no surface indications. However, the probable limits of ore-bearing area are indicated on the accompanying map.

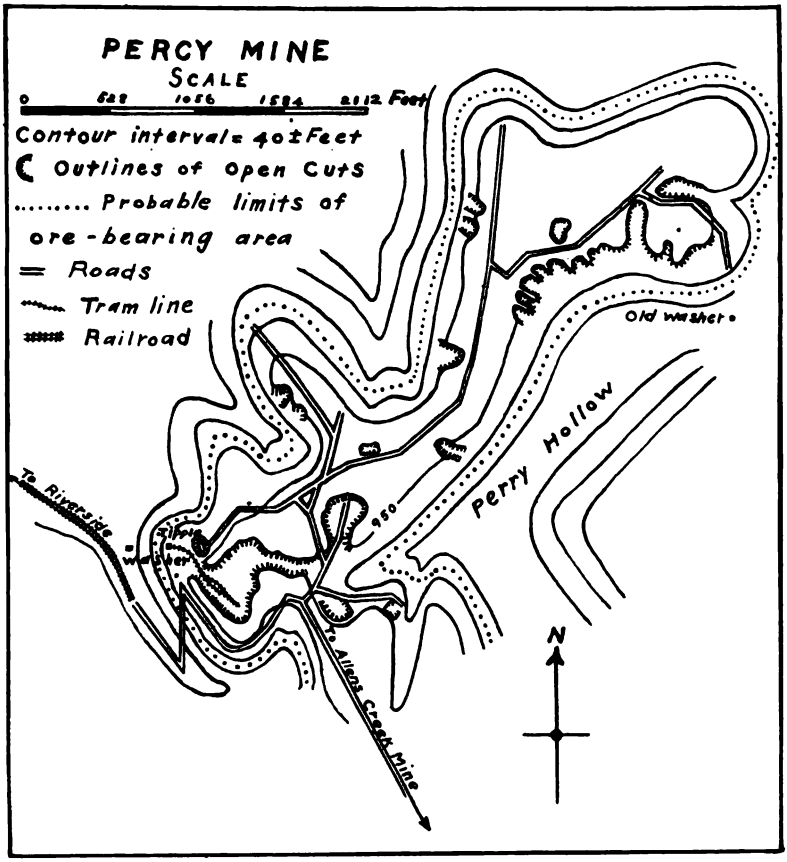


FIG. 13. Mine No. 60 of the Lewis County map.

Most of the ore is of good quality, but a highly siliceous material of little or no value occurs. The good ore is a dark-brown limonite, which has a texture varying from compact to cellular. The chief siliceous impurity is chert, though sand and quartz are sometimes embedded in the ore.

This property was purchased by the Warner Iron Company on March 28, 1899, and the bank was opened in that year. It has been worked intermittently from 1899 to the present time. The total production to date is 250,000 tons. An average analysis of the ore showed 46.5 per cent. iron; 0.25 per cent. manganese; 1.15 per cent. phosphorus; 0.019 per cent. sulphur; and 18.69 per cent. insolubles.

Digitized by Google

A double steel log washer of the McClanahan & Stone type is used at this mine, which has a capacity of 350 tons per day. The mining is done with steam shovel, and tram haulage is used to transport the ore to the tipple. The total average number of employes is about 55.

ALLENS CREEK MINE.

(No. 61, Lewis County map.
Owned by the Bon Air Coal and Iron Company, Nashville, Tennessee.)

This is one of the largest iron ore mines in the southern portion of the Western Iron Ore Region. It is located in the extreme northeast corner of Wayne County, about $\frac{3}{5}$ of a mile northeast of Allens Creek, and adjoins on the north the Percy mine of the Warner Iron Company. Nearly all the worked portion of the mine lies in Wayne County, and for that reason the bank will be only briefly described here. However, the local segregations of ore composing the Allens Creek deposits extend into Lewis County, and this forms one immense bank.

The Allens Creek mine is situated on the crests of high ridges and their spurs at an elevation ranging from 900 to over 950 feet above sea level. The deposits are pockety, and occur in the loose material overlying the St. Louis formation. A 60-foot section of cherty limestones is exposed on the lower west slope of the ridges near the creek. There are no outcrops of bedded rocks in the immediate vicinity of the ore, nor have they been encountered in any of the workings. It is evident, therefore, that the loose material extends to a great depth, and on the crest of the ridges it probably has a thickness of over 125 feet.

Brown ore in the form of small and large bowlders and fragments outcrop at intervals over an area of approximately 500 acres. The exposures occur on the slopes to hollows, around the heads of draws, and in other favorable situations where the overburden has been largely removed by erosion.

Mining has been conducted by one large, practically continuous opening, and many small cuts. There are quite a number of shallow test pits scattered over parts of the undeveloped areas, but the prospecting has not been thorough. The large cut contains an area of about 12 acres, and the remaining cuts aggregate approximately 8 acres. The total number of acres worked over is, therefore, about 20. The workings have reached a maximum depth of 60 feet, but in many parts it is less than 40 feet. The ore extends to an unknown depth and the bottom has not been reached at a depth of 60 feet. The overburden varies from nothing to over 15 feet.

A cross section in the mine often shows clay, water-worn gravel, chert layers, ore, shale, and angular weathered chert. A part of the material is apparently of alluvial origin. There is no orderly arrangement of material, and the ore is found in pockets irregularly distributed through the mass. The upper part of the section is chiefly composed of very red clay which is often so rich with shot ore that it can be profitably handled in the washer. The pockets vary in size and have an irregular outline, or are tabular and lens shape. They lie flat, or may be inclined at any angle, and sometimes produce hundreds of tons before they run out. Rich pockets are often found where there are no surface showings.

The ore is a dark-brown limonite, but some of it is probably goethite. It is of excellent quality and occurs in the compact and cellular forms. The chief siliceous impurity is chert. A highly siliceous ore is sometimes met with in certain parts of

Digitized by Google

the bank. An average analysis showed 51 per cent. iron; 0.87 per cent. phosphorus; 0.22 per cent. manganese; trace of sulphur; and 10 per cent. insolubles.

The Allens Creek mine was opened by the Southern Iron Company of Nashville, in the year 1891. This company operated the mine until 1892, when it was closed and remained so until 1895. It was then sold to the Buffalo Iron Company of Nashville, and operations were resumed in October, 1895, and continued until July, 1902. The property was then acquired by the Bon Air Coal and Iron Company, which has continued operations till the present time, 1913.

It is estimated that the mine produced 75,000 tons prior to October 1, 1895. From that date to April 1, 1913, the total output was 1,054,331 tons. The tonnage remaining in the deposit has been estimated to range from 3 to 9 million. The company owns 5000 acres in the vicinity of Allens Creek of which 500 acres are reported as ore-bearing.

This property is well equipped for mining opertions. A double log steel washer of the McClanahan & Stone type with three sets of jigs is used. It has a capacity of 400 tons per day. The ore is mined by means of steam shovels. Two furnaces were erected in 1892, and were operated with charcoal until 1900. In that year the experiment was tried of using both charcoal and coke, but this was not successful, and the use of coke alone was taken up.

CHRISTIAN BANK NO. 4.

(No. 62, Lewis County map.
Owned by H. T. Christian, Riverside, Tennessee.)

This deposit, located 1⅗ miles north, 50 degrees east of Riverside, is situated on the top of a secondary ridge, which is on the east side of Piney Hollow. That part of the ridge where the ore occurs has an elevation of between 850 and 900 feet above sea level, and is about 250 feet higher than Buffalo River.

Bowlders and fragments of limonite occur over an area of 5 or 6 acres. Some of the ore is embedded in the soil, but most of it is loosely distributed over the surface. Chert fragments are abundant on the top and slopes of the ridge. Bowlders of cherty ore and lumps of good ore were found on the side of ridge 20 feet below the top. Two shallow pits have been dug, both of which show some ore in red clay. The ore from one of the pits is very cherty, but a fair quality was removed from the other. Most of the ore seen at this bank was rather siliceous, chiefly due to embedded chert.

ROCHELL AND SLAYTON BANK.

(No. 63, Lewis County map.
Owned by M. R. Rochell, Hohenwald, Tennessee, and T. J. Slayton, Clarksville, Tennessee.)

This bank, located 1⅕ miles north, 35 degrees east of Riverside, is situated on a secondary ridge on the west side of Piney Hollow. The bank lies about 75 feet below the crest of the main ridge, and the elevation is about 825 feet above sea level, or between 200 and 250 feet above Buffalo River. The outcrop extends over an area of possibly 5 acres, and consists of an occasional bowlder embedded in the soil and of smaller pieces of ore scattered over the surface. Within this area 6 test pits have been dug, ranging from 2½ to 4½ feet in depth. Only one of the pits shows any marked amount of ore, but most of the holes show considerable shot

Digitized by Google

ore in very red clay. Some of the ore is very cherty, but that of good quality also occurs. Surface indications were noticed at several points north of here, near the crest of the main ridge.

BROWN PROSPECT.

(No. 64, Lewis County map.
Owned by C. M. Brown, Napier, Tennessee.)

This prospect is located 3⅖ miles south, 80 degrees east of Riverside, and 1⅕ miles south, 11 degrees east of the junction of Chief Creek with Buffalo River. It is situated on the crests of a high secondary ridge and its spurs, west of Brush Creek. The ridge and its spurs have an elevation of 950 feet, and their crests are nearly 300 feet higher than Buffalo River.

Surface indications consists largely of a few fragments of loose ore, but chunks and lumps occasionally occur, embedded in the clay soil. Root-wads frequently show shot ore. These exposures sparingly occur over an area of several acres. The surface ore is a light-brown siliceous limonite, which analyzed 36.3 per cent. iron; 34.22 per cent. silica; .232 per cent. phosphorus; and .086 per cent. sulphur.

Water-worn quartz and chert gravel is abundant on the tops of the ridge and its spurs, and if ore exists here in quantity it is evidently covered by these deposits. Surface showings extend over into lands owned by the Davidson, Hicks & Greene Company.

DAVIDSON, HICKS AND GREENE COMPANY TRACT (SMITH TRACT).

(No. 65, Lewis County map.
Owned by the Davidson, Hicks and Greene Company, Nashville, Tennessee.)

This tract is located 3 miles southeast of Riverside, but the outcrop of brown ore here described is located ⅖ of a mile south, 10 degrees west of the Brown prospect, and on the same secondary ridge as the latter. At this place limonite is exposed around the head of a hollow near the crest of the ridge, and only a few feet west of, and near the crook in the ridge road. The outcrop covers an area of several hundred yards and consists chiefly of bowlders and fragments embedded in the soil. A few thousand feet west of this place, several very shallow test pits were found, near the ridge road leading to Allens Creek. Some of these showed a little shot ore in red clay, but the pits are entirely too shallow for test purposes. The only chance of finding much ore on the crest of the ridge is by sinking deep shafts.

Limonite is reported to outcrop at a number of places between this locality and Perry Hollow, which is 1⅖ miles southeast of Riverside. The writer did not go over this area in detail, but had seen enough to convince him that the section will warrant systematic prospecting.*

MID-BRUSH CREEK DEPOSITS.

These deposits are located 4 miles southeast of Riverside, between Little and Big Brush creeks. They are situated on a high ridge and its spurs at an elevation ranging from 900 to nearly 1000 feet above sea level. The deposits consist of 3 distinct banks situated only a short distance apart, but separated by apparently bar-

* Prospects numbered 66 and 67 on the map of Lewis County, were incorrectly located. As those are not in Lewis County, their descriptions are omitted.

Digitized by Google

ren ground. The topographic relations of the banks and the approximate limits of the outcrops are shown on the accompanying sketch map.

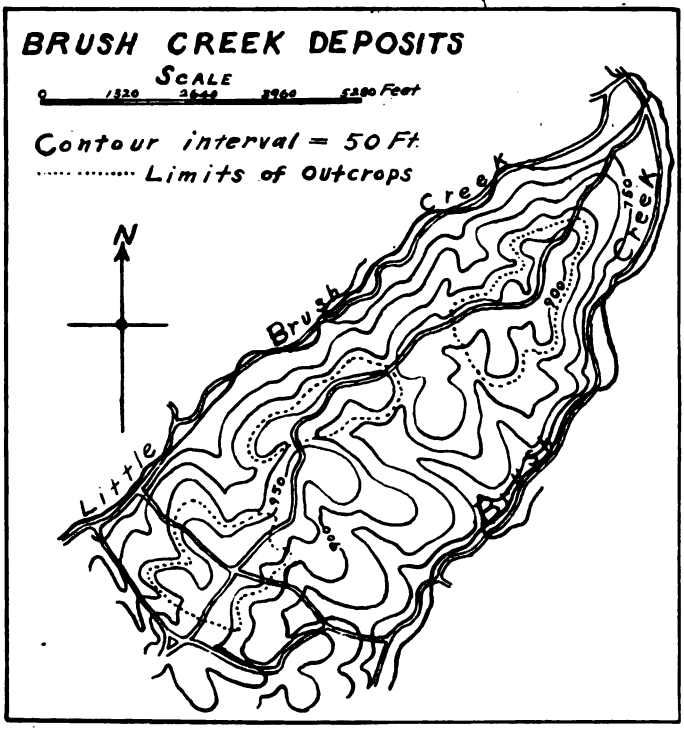


FIG. 14.

Estimates, regarding the quantity of ore present in these banks, have varied widely among those making them. As no systematic prospecting has been done, the value of the banks can not be determined from the outcrops and the few shallow test pits. The three banks are described below.

BRUSH CREEK BANK NO. 1.

(*No.* 68, *Lewis County map.*
Owned by the Napier Iron Works, Nashville, Tennessee.)

This bank is located 4 miles south, 40 degrees east of Riverside. The topographic relations and exact situation are mentioned above. Bowlders and fragments of brown ore are exposed over an area of 48 acres. Within portions of this area the surface is thickly strewn with ore. It has been prospected by ten shallow pits, most of which are 10 to 12 feet long, 4 to 6 feet wide, and 3½ to 4½ feet deep. All but 3 pits show more or less ore, and 2 make a good showing. The ore occurs in very red clay which contains variable amounts of water-worn gravel and angular chert.

Rocks outcrop on the east slope of the ridge at approximately 60 feet below the top. Residual ore is exposed 30 feet or more below the crest of the ridge. It is apparent, therefore, that the ore extends to a depth of at least 30 feet.

Digitized by Google

BRUSH CREEK BANK NO. 2.

(No. 69, Lewis County map.
Owned by the Napier Iron Works, Nashville, Tennessee.)

This bank is located 3⅗ miles south, 45 degrees east of Riverside, and about ⅗ of a mile northeast of Bank No. 1.

The outcrop consists of bowlders and fragments of ore scattered over an area of about 35 acres. Two shallow test pits were found in this area, and these show some ore in very red clay which contains chert fragments.

BRUSH CREEK BANK NO. 3.

(No. 70, Lewis County map.
Owned by the Napier Iron Works, Nashville, Tennessee.)

This bank is located 4 miles south, 55 degrees east of Riverside, and ½ mile northeast of Bank No. 2.

The outcrop consists of bowlders and fragments of brown ore scattered in patches over an area of approximately 50 acres, within parts of which the surface is thickly covered.

The bank has been prospected by 6 shallow pits, 2 of which are blank, remainder showing some ore, principally shot ore. The material in which the ore occurs is chiefly very red clay. The bank should be thoroughly prospected.

The ore is a dark-brown limonite of good quality. It has a texture varying from compact to cellular, but the compact variety is the most abundant. A sample analyzed 54.08 per cent. iron; 5.79 per cent. silica; 1.916 per cent. phosphorus; and .056 per cent. sulphur.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Digitized by Google

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

Digitized by Google

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert R. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

Digitized by Google

Vol. III. No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

Vol. III. No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

Vol. III. No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf .P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

Digitized by Google

Vol. V. No. 1—The Hydro-Electric System of Tennessee, by J. A. Switzer.
West Tennessee Gullied Lands and Their Reclamation, by R. S. Maddox.
The White Phosphates of Tennessee, by J. S. Hook.

No. 2—Physiographic Influences in the Development of Tennessee, by L. C. Glenn.
Care and Protection of Forests, by R. S. Maddox.
Two Natural Bridges of the Cumberland Mountains, by Wilbur A. Nelson.

Digitized by Google

Tennessee. Geol. Survey, 1909-
SESSIONS ROOM
RECEIVED
OCT 4 1915
UNIV. OF MICH.
LIBRARY
TN
24
T2
A4

Volume V OCTOBER, 1915 Number 4

THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY, AND OCTOBER
BY THE STATE GEOLOGICAL
SURVEY
NASHVILLE, TENNESSEE

A Magazine Devoted to the Description, Conservation, and Development of the Resources of Tennessee

CONTENTS

The Soils of Tennessee.....C. A. Mooers
Recent Oil Development near Oneida, Scott County, Tennessee.....L. C. Glenn
Publications of the Geological Survey of Tennessee.

Entered as second-class matter January 10, 1913, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

Volume V Number 4

OCTOBER, 1915

TN
24
.T2
A4

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey

NASHVILLE, TENNESSEE

STATE GEOLOGICAL COMMISSION

Gov. TOM C. RYE, *Chairman*

Dr. BROWN AYRES, *Secretary*
President, University of Tennessee

H. KNOX BRYSON
Commissioner of Agriculture

Dr. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

R. A. SHIFLETT
Chief Mine Inspector

GEOLOGICAL CORPS

A. H. PURDUE
State Geologist

OLAF P. JENKINS
Assistant Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

CONTENTS

The Soils of Tennessee.....C. A. Mooers
Recent Oil Development near Oneida, Scott County, Tennessee.....L. C. Glenn
Publications of the Geological Survey of Tennessee.

Digitized by Google

Typical view of upland plateau of West Tennessee.

Digitized by Google

The Soils of Tennessee*

By C. A. Mooers.

INTRODUCTION.

Tennessee upland soils are of residual origin. That is, they were formed where they lie, or nearly so, by the weathering of rock, or of other geological material, similar to that which now underlies them. Each kind of rock or other material gives rise to a definite kind of soil as is evidenced by a certain uniformity of color, texture and plant food supplies. The line of demarkation between these different soils is often surprisingly easy to distinguish. For example, in a valley where the two soils meet, it is frequently possible to stand with one foot on the heavy yellowish-gray soil derived from the Chickamauga limestone and the other on the brown-colored loam, whose origin is the Holston marble. Where the marble outcrops above the blue limestone, the brown loam may be carried down and over the blue limestone and often at such a depth that the latter has no appreciable effect on the surface soil.

The fact that each geological formation produces a characteristic soil accounts for the remarkable difference in both the fertility and crop adaptability of the various areas throughout the State. Poor land may lie in juxtaposition to that whose agricultural value is several times as great, not because of differences in cropping and manuring, but because of some fundamental differences in the rock from which each was derived.

In this article the geological basis of classification will therefore be followed for the upland soils. The alluvial soils cover a relatively small area and vary greatly in character, which is governed in a large part by the velocity of the stream current at the time of the deposition, but also by the origin of the water-borne material.

*Requests often come to the State Geological Survey for information concerning the soils of Tennessee. The large number of surface divisions of the State and of geological formations that have produced its great variety of soils, have made it difficult satisfactorily to comply with these requests. For this reason Professor Mooers, who is the best authority we have on the soils of Tennessee, was requested to prepare this paper. If the reader can have before him, the geological map of the State, published by this Survey, his interest and understanding of the paper will be much greater than it can be without the map.—A. H. P.

Digitized by Google

In a general way there is considerable similarity in the texture of the upland soils. Throughout the State the prevailing types are silt loams and loams, and there is one large area, the Cumberland Plateau, covered with fine sandy loams. True clay soils are rare, and true sandy soils are almost unknown except along the river banks. The subsoils are heavier than the surface ones and include heavy silt loams, clay loams and clays.

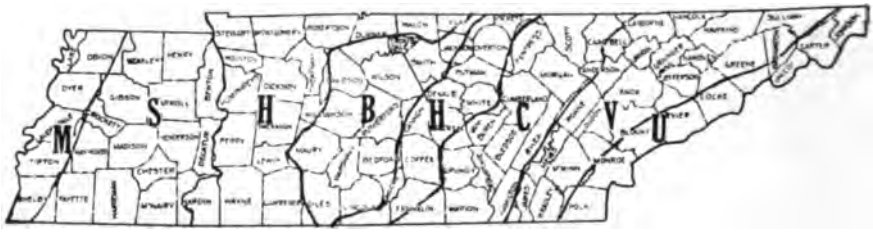


FIG. 1. Map showing the physiographic divisions of Tennessee.
U. Unaka Chain, or Smoky Mountains.
V. Valley of East Tennessee.
C. Cumberland Plateau.
HH. Highland Rim.
B. Central Basin.
S. Slope of West Tennessee.
M. Mississippi Bottoms.

For convenience in reference, as well as for other reasons, each of the natural divisions of the State is considered separately. They differ appreciably in both elevation and topography. East Tennessee is the most elevated and contains the Smoky Mountains on its eastern border and the parallel ridges and valleys which make up the broad depression of the Great Valley of East Tennessee, lying between the Smoky Mountains and the Cumberland Plateau. Middle Tennessee has been likened to a dinner plate, the Central Basin corresponding to the bottom of the plate; and the Highland Rim to the rim of the plate. The hills of the Basin are inclined to be either isolated or in groups rather than forming parts of ridges.

The Cumberland Plateau, which forms a part of both East and Middle Tennessee, must, however, be considered separately, as it is distinctly different in both soil and climate from any other large area in the State.

West Tennessee has the lowest elevation of the three divisions of the State, and may be described as an undulating slope, extending from the Highland Rim on the east to the Mississippi River on the west.

THE SMOKY MOUNTAINS.

The Smoky Mountain section is a narrow belt from two to twenty miles wide along the eastern border of the State, and has an area of about 2000 square miles. The altitude varies from 2000 to 6000 feet, with occasional

Digitized by Google

depressions as low as 1000 feet. This is the roughest and most mountainous part of the State, and for the most part is not at all suitable to cultivation.

The soils are apt to be shallow and rocky, even on the tops of the mountains, which have been used for many years for summer grazing grounds for cattle, and to a lesser extent for other stock. The mountain sides are very steep with usually very narrow valleys, but occasionally a wide valley or "cove" is found where the soils and the farming conditions are practically the same as in the Great Valley. Also along the foothills are some farms and orchard sites. This section has furnished much timber and is now being purchased to considerable extent by the Federal Government for forest reserves.

THE GREAT VALLEY OF EAST TENNESSEE.

The Great Valley of East Tennessee comprises the section lying between the Smoky Mountains on the east and the Cumberland Plateau on the west, and covers about 9200 square miles. It is drained by the Tennessee River and its tributaries, and is an especially well-watered section of the State. The most prominent types of soil will be discussed under the headings which follow and which are indicative of the soil origin.

Marble and other high grade limestone soils.—The decomposition of marble and other high grade limestones has given rise to the most fertile and durable lands found in East Tennessee. These soils are distinguished by their color, which varies from a rather dark brown to red. They are brown-colored when newly cleared and where fertility has been maintained by good methods of farming. Where cropped for many years in corn, wheat, etc., with little regard to the maintenance of fertility, the brown color changes gradually to red, and the more the soil has been eroded and worn the lighter is the color.

These soils are for the most part loams, with rather heavy clay loam subsoils, and are naturally well suited to all of the common farm crops, such as corn, wheat, clover and grass, and forage crops in general. Also they are well, but not richly, supplied with all of the elements of plant food. Under live stock farming supplemented by good methods of soil management and cropping, fertilizers are not necessary, and even liming may not be profitable. They are not, however, rich in lime, a few tenths of a per cent. being all that is found by the chemical analyses that have been made. Where crops have been removed for years with little return of fertility, which is unfortunately the custom, liming is apt to be profitable, and may even be a necessity in order to grow red clover; for growing alfalfa, liming is even more necessary. Also phosphatic fertilizers may be found profitable under these conditions.

Digitized by Google

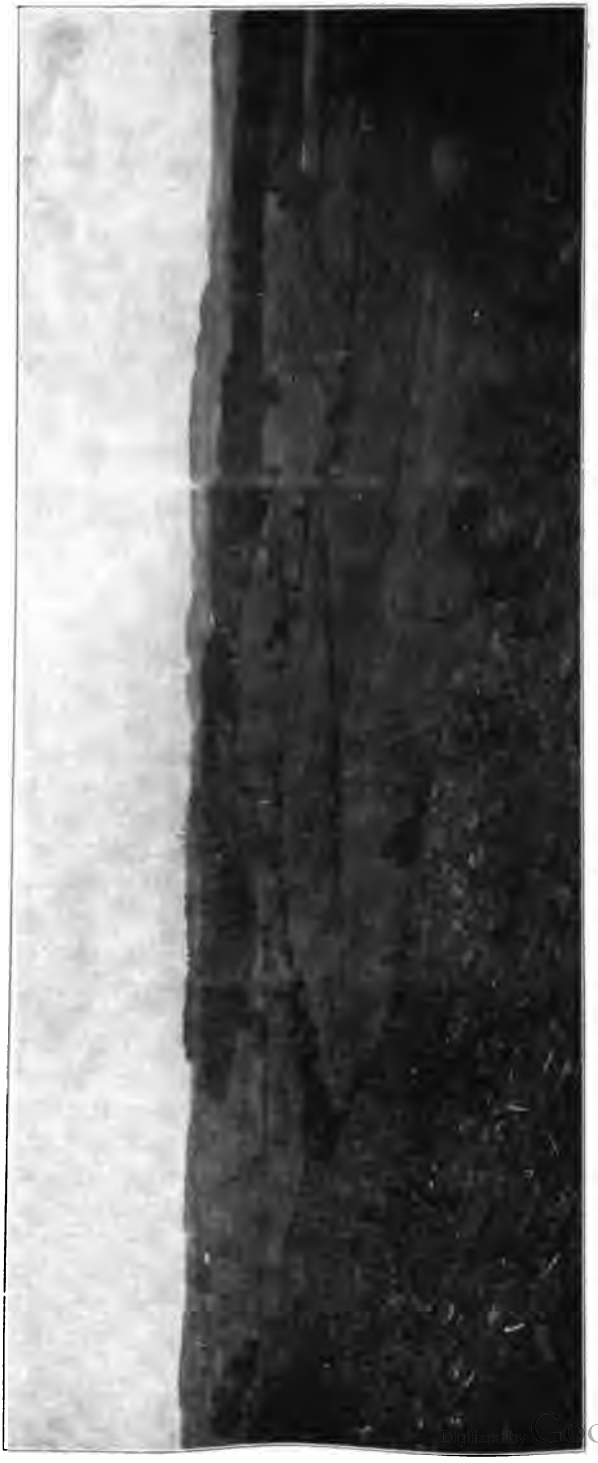


FIG. 2. East Tennessee landscape.

Digitized by Google

But even when run down, these soils respond readily to proper treatment and can be restored to high productiveness. Alfalfa is more easily obtained on them than on any other type of upland in this part of the State at present known to the Agricultural Experiment Station of the University of Tennessee, and farmers are finding this crop very profitable. As they are superior soils, it is not surprising to find them relatively high priced, forty to one hundred dollars an acre being not unusual. The chief drawbacks to these soils are the ease with which they are eroded when in cultivated crops, and the fact that outcrops of limestone rock prevent some parts from being cultivated. Bluegrass thrives, however, in such places and makes excellent pasture.

The soils described are found both on hillsides and in valleys wherever the marble formation occurs. They cover only a relatively small area, being found in narrow belts throughout the valley section.

Dolomitic soils.—The underlying rock over approximately one-half of the Great Valley is dolomite or magnesian limestone. This formation has given rise to soils which vary in both color and fertility, but which have certain characteristics in common. They may be roughly placed in two groups, the ridge or high hill lands, and the undulating lower lands. The former are lighter in color, contain much more coarse, angular gravel or chert, and are poorer than the latter. In fact, the dolomite ridges of East Tennessee are among the poorest soils of the State, being naturally very deficient in phosphoric acid and lime, and not well supplied with either potash or nitrogen. They are gravelly loams which are generally gray colored, but some are red colored and all have red colored subsoils. These soils are deep, well drained, stand drought as well as any, and respond readily to both manure and fertilizers.

The high elevations of the ridges, together with the nature of the soils, makes them well adapted to peaches, cherries and early apples. Grapes and small fruits thrive, and in some places strawberry growing in particular, has reached considerable commercial importance. These ridge lands are little used for general farm crops, and as a rule are covered with timber. Land values are low, ten to twenty dollars per acre being common prices.

The lower lands contain less chert and are apt to be redder colored than the ridge lands. The surface is rolling but is not unsuited to cultivated crops. These soils are nearly always somewhat deficient in both lime and phosphate and are apt to be poor in nitrogen and humus. They are best adapted to corn, wheat and forage crops, and when limed and fertilized will produce good crops of clover and grass. At the University Farm at Knoxville, alfalfa is successfully grown on this type of land, but not without special preparation.

Digitized by Google

In some instances the valley lands of dolomitic origin, especially where the dolomite is interstratified with non-magnesian limestone, are brown to dark-red in color, and are of extra fertility, ranking with the best limestone soils in this part of the State. Areas of this kind are found, for example, in the vicinity of Morristown and New Market.

Chickamauga limestone soil.—The Chickamauga or blue, "rotten", limestone is found throughout the East Tennessee Valley in narrow strips, which are often only one-eighth of a mile in width, but which may be fifty or more miles in length, running in a generally north-easterly and south-westerly direction. Upon disintegration, this rock produces heavy silt loams and clays, which may be dark colored when first cleared but under cultivation become gray and reddish yellow, the latter being the characteristic color of the subsoil. As this formation weathers easily, the soils are found in valleys and on low hills. Outcrops of the rock are not infrequent, and often are marked by cedar groves. Where of good depth, the soil is adapted to corn, wheat, forage crops and grass. Soil analyses and the results of field experiments show that this type is generally poor in phosphoric acid and lime, but rich in potash. The long cultivated lands are generally poor in nitrogen.

Fall plowing is especially advisable on this type of soil, in order to get a mellow seed bed for any summer crop. Liming is generally a necessity for a satisfactory growth of clover, and the use of phosphate should not be omitted.

Tellico sandstone soil.—The Tellico sandstone formation is found in narrow belts, generally occupying, on account of the hardness of the rock, the tops of the highest hills and ridges. The soils derived from it cover the tops and sides of the hills and may extend down to the valleys. They vary from brown to red in color and in general appearance might easily be confused with the marble soils previously described. Both kinds are often called "mulatto" soils. The Tellico sandstone soils are, however, much lighter than the marble soils, being classified as fine sandy loams. Both on account of their elevation and their texture, they are especially well suited to market garden crops, orchards and small fruits. When first cleared, they are well supplied with all of the elements of plant food, but the long cultivated soils need fertilizers and lime. With attention to these needs, alfalfa as well as clover may be grown successfully. Owing to the steepness of the hillsides which characterize this formation, erosion is liable to do great damage. This should be prevented by putting them in permanent pasture before the soil fertility is greatly reduced. Failure to do this has in many instances resulted in irreparable ruin.

These soils are by far the easiest tilled of any uplands in this part of the State. Winter cover crops, such as crimson clover, vetch and even

Digitized by Google

rye, should be considered very important and may be turned under to advantage in the spring in preparation for a summer crop. Unfortunately the area covered by this type of soil is small and much of that is too steep for continued cultivation.

Soils of shale origin.—Shale or slate is found to a greater or less extent in various formations, such as the Tellico sandstone and Chickamauga limestone; and it makes up the body of other formations in which marble or limestone sometimes appears instead of shale, as is frequently true of the Sevier shale. The shales vary considerably in both chemical composition and color, which varies from red and yellow to black. Yellow and reddish colored shales are very common, and produce gray and yellowish colored soils with reddish yellow subsoils. They are often shallow and lacking in fertility. In fact, most soils of this kind are rated as the least desirable of all. They occupy lowlands in large part, but outcrops appear at all elevations.

Where these soils are of good depth, and especially where some limestone was mixed with the shale, they are fairly well suited to corn, wheat and grass, redtop in particular. Gray colored silty soils, often spoken of as "crawfishy", result from the decomposition of shale, and are especially poor and difficult to handle profitably.

Both chemical analyses and field experiments indicate that phosphate and lime are the chief mineral elements needed. Soils derived from the black shale, however, are often well supplied with lime and produce excellent crops of clover. Poverty in nitrogen is the rule. This may be remedied in part at least by the sowing of Japanese clover, to which they seem to be well suited, and by using the land for pasture purposes.

Overflow and bench lands.—Wide expanses of alluvial soils are of rare occurrence in Tennessee, but along the rivers and streams are found narrow belts of such soils, which are of considerable importance in the aggregate. The first bottom is the name often used for the portion which is overflowed annually. As a rule this is a sandy soil of high productiveness and is used almost exclusively for corn. The second bottom, or bench, which is seldom overflowed, contains more clay and other fine particles. Much of this is a fine sandy loam, but where deposition occurred in relatively still water, a heavy soil results.

The bench lands are generally very productive, and although corn is the common crop, they are well suited to clover and grass as well as to other forage crops. Much of them is too rich for wheat. These are naturally very valuable lands, but as they do not receive enough deposits from overflows to maintain their fertility, they have been reduced greatly in productiveness and are apt to be in need of manuring. Systematic crop rota-

Digitized by Google

tions, which include clovers and other legumes, should be practiced on them. At the University farm these soils have not been found responsive to phosphating, except for alfalfa, but to be somewhat in need of lime for both clover and alfalfa.

Lying above the second bench may be found a third bench which is never overflowed now, but which in times past received river deposits, and was in fact formed in large part in this way. With this ancient river deposit, material from the neighboring uplands has been washed in and the soils are therefore of mixed origin. They are often more productive than the adjacent uplands, but vary with them in general character.

THE CUMBERLAND PLATEAU.

The Cumberland Plateau is an elevated tableland from 30 to 50 miles wide, extending across the State from Kentucky to Alabama. The area is about 5000 square miles. The average elevation is not far from 1800 feet, or nearly 1000 feet above the Great Valley of East Tennessee, or the Highland Rim of Middle Tennessee. The plateau is practically undeveloped from an agricultural point of view but offers many inducements to settlers.

The major part of this section is gently undulating, but there are areas so hilly and rough as to be unsuited to cultivated crops. The area of uncultivable land is further increased by the outcropping of the sandstone rock, which is near the surface over much of the area. The soils at best are shallow, two to five feet being common distances to the underlying rock of the cultivated fields. However, the rainfall is generally ample, being well distributed, and amounting to about 55 inches per annum, so that crops appear to suffer less here from dry weather than on the deep limestone soils of other sections. The prevailing soils are fine sandy loams which have good retentive subsoils. They are easily tilled, and on account of their excellent texture are suited to trucking crops, orchards and small fruits.

The prime cause of the lack of agricultural development is that the soils are naturally very deficient in both phosphoric acid and lime. This conclusion was reached from the results of chemical analyses of the soils and from field experiments which have been conducted by the Agricultural Experiment Station for the past eight years. Fortunately both of these elements can be supplied from deposits within the State at an expense which is not at all prohibitive of profitable results. At Crab Orchard on the line of the Tennessee Central Railroad, a thick bed of high grade limestone outcrops on the plateau and insures an inexhaustible supply of cheap limestone to that vicinity. Cumberland County has recently installed a crushing plant there and sells the rock at cost.

Digitized by Google

The supply of potash is indicated as poor by the chemical analyses, but the results of field experiments have seldom shown profitable returns from potash salts, even on long cultivated soils. However, under more intensive crop production than is now the rule, some potash is apt to be needed and is generally advisable for potatoes and trucking crops. The nitrogen and humus supplies of the new lands are fairly good, but very poor for the long cultivated ones. Attention must therefore be given to the maintenance of these supplies, which should not prove difficult with the information now available on this subject.

At the present time corn, forage crops, potatoes, apples, etc., are being grown to a limited extent. The chief dependence outside of the timber for an income, is the great free range where cattle and other live stock are fattened with the minimum of expense to the owners. Only a small portion of the land is cleared, though much of the best timber has been removed, and by burning over the land each year the growth of wild grass has been encouraged, though at the expense of the soil supply of vegetable matter.

The Agricultural Experiment Station has published a practical guide on the upbuilding of these soils for which lime and phosphate must be considered of fundamental importance.

THE CENTRAL BASIN OF MIDDLE TENNESSEE.

The Central Basin of Middle Tennessee has an area of approximately 5400 square miles. It is an undulating plain, 50 to 60 miles wide and 100 miles long, and has a general elevation of about 600 feet above sea level, but hills rising to 200 or more feet above the surrounding country are not uncommon. The soils are practically all of limestone origin, and are decidedly the most durable and productive under cultivation of any large area in the State.

The typical soil is a deep, brown loam which is easily tilled and is well adapted to a great range of farm and garden crops. In its virgin condition this type of soil was rich in all of the important elements of soil fertility, but continuous cropping in corn and wheat has greatly depleted the store of nitrogen. Also they are now in large part in need of liming to get satisfactory crops of clover. To restore these lands to their former productiveness the growing of legumes, clovers in particular, is a prime essential. With the aid of lime this can easily be done. The continuation of the present system of cropping will result in the further depletion of these naturally very fine soils. The loss of soils by erosion is also a serious matter and calls for the growing of much more grass than is the present custom.

Digitized by Google

According to the results of numerous field experiments, the adding of neither potash nor phosphate is apt to be profitable on the typical brown loam, so far as general farm crops are concerned. Chemical analyses show this type of soil to be especially well supplied with phosphate. Instances have been found, however, where acid phosphate has proved profitable, especially for some quick growing crop like Irish potatoes or alfalfa.

Red-colored loam.—In the vicinity of Murfreesboro are red-colored soils which differ somewhat from the typical brown loams of the Central Basin. In particular they are not so well supplied with phosphate, so that they respond readily to applications of acid phosphate. This type of soil

FIG. 3. Typical scene in the bluegrass section of Middle Tennessee.

has been planted extensively in cotton, as well as in corn and wheat, until its productiveness has been greatly reduced. Here again, greatly increased attention should be given to the growing of clover, alfalfa and grass, which can be materially assisted by liming and phosphating.

Phosphatic soils.—Phosphate rock is found at different points in the basin and has given rise to some very rich, brown-colored, loamy soils which have an extra high content of phosphoric acid.

Under the usual system of cropping, these soils are apt to become poor in nitrogen and in some instances are greatly impoverished. For such a condition phosphate fertilizers are not only inefficient but are entirely un-

Digitized by Google

warranted. Nitrogenous fertilizers, such as nitrate of soda, dried blood and cotton-seed meal, may be used to a limited extent, but the production of clover and alfalfa, the pasturing of land, and the careful saving and use of barnyard manure, are the important means of their permanent improvement.

Gravelly hill lands.—The gravelly hill lands of this section are known for their productiveness, and in this respect are the opposite of the gravelly hills either of East Tennessee or the "barrens" of the Highland Rim. The soils are loamy and of excellent texture. The great drawback to much of this area is the steepness and height of hills, which make manuring almost impossible, and limit the use of implements and farm machinery. These lands make very fine bluegrass pastures, and clovers generally thrive. By utilizing them for these purposes, the fertility is easily maintained. Neither fertilizers nor lime is apt to be required, but the need of the latter is sometimes indicated for old and depleted soils of this character.

Glady lands.—In the aggregate, a considerable area of the basin is not suited to cultivated crops, on account of either the outcropping of the limestone or of the shallowness of the soil overlying the rock. Such areas are naturally covered with cedars and are known locally as cedar glades. "Glady" land is therefore land of shallow soil, but is used profitably both for pastures and for the production of cedar timber.

Gray-colored soil.—In addition to the soils mentioned, certain minor areas of gray-colored soils with yellowish-red subsoils are found. They are heavier and not so fertile as the typical brown loams, and have been found to respond to both phosphate and lime. They make excellent wheat and grass lands when properly handled.

Overflow and bench lands.—The overflow and bench lands of this part of the State are in general very rich, and are not apt to require much if any artificial drainage. As in East Tennessee, the texture of the overflow lands varies greatly, depending upon the swiftness of the current at the point of deposition. Sandy soils and sandy loams are the rule. The bench lands are apt to partake of the nature of the adjacent uplands, but are deeper and richer. At the present time, the bench lands are more or less reduced in fertility, by reason of long continued cropping in corn. They should be set oftener to clover and grass, and a better rotation of crops than that commonly followed is highly advisable.

THE HIGHLAND RIM.

The Highland Rim, which completely surrounds the Central Basin, has an approximate area of 9300 square miles, and an elevation of 800 to 1000 feet above sea level. The average annual rainfall of nearly 50 inches is

Digitized by Google

well distributed throughout the year. The average date of the last killing frost in the spring varies according to the locality, from April 8 to April 20. In a similar manner the average date of the first killing frost in the fall, varies from October 8 to October 26.

The surface varies from gently undulating to hilly, but in general lies well for cultivated crops. The soils may be roughly divided into two large groups, one on the outer part of the rim, consisting of those derived from the decomposition of limestone; and the other on the inner part, derived from siliceous or "freestone" formations.

Limestone soils.—Over large areas the limestone soils are readily distinguished by their dark-brown color, where recently cleared and improved, and by their red or "mulatto" color where cultivated and worn. In physical character, crop adaptability and color, this type is very similar to the high-grade limestone soils of East Tennessee. Alfalfa has done especially well on it. Other areas of limestone soils consist of grayish and brownish loams, which are often gravelly, and which have red subsoils. Some of the brown-colored soils are naturally rich, and are adapted to a great variety of crops, including tobacco. The gray soils are inferior to the others, and may be even classed with the "barrens" type, but are excellent tobacco soils.

FIG. 4. View in Robertson County, northeast of Adams.

All these soils are of good depth and the drainage is adequate. Up to the present time grain farming has predominated. Tobacco has been an

Digitized by Google

important crop in some counties, Montgomery and Robertson in particular. Nursery stock has been produced extensively in Franklin County and peanuts in Perry and Humphreys counties. There is every indication that the production of these special crops could be greatly increased.

The results of chemical analyses and of field experiments show that both lime and phosphoric acid are generally deficient. The better class of these soils will, however, produce excellent crops of clover when first cultivated, but in the course of time liming becomes necessary to their successful culture, and is even more important for alfalfa. The supply of potash appears fairly ample, at least for general farm purposes. The farmers long ago found out the value of phosphate, but only in the last few years has special attention been called to the importance of liming.

The nitrogen and humus content, though fair when the land was first cleared, has been greatly reduced under cultivation. As for other soils the remedy lies in the growing of legumes, alfalfa and clover in particular, and in live stock farming, which will warrant grass pastures and reduce the area now planted to grain crops.

The "barrens" type.—On the inside of part of the rim, and completely encircling the Central Basin, are found gray-colored soils, which are derived largely from siliceous formations, but in part from limestone containing much chert. There is a considerable variation in this class of soils, some being gray-colored with a gray subsoil and locally known as "crawfishy" land; others are gray-colored with a yellowish subsoil, and a third type is gray to a light-brown in color with a red-colored subsoil. The last type is considerably superior to the first or crawfishy type and is also superior to the second. The area covered by these soils is relatively large. The surface varies from gently undulating to hilly—the latter being gravelly and very poor.

These soils are silt loams of good texture and structure except where very deficient in vegetable matter. The depth to the underlying rock is ample and the drainage is generally good, but may be poor, especially on the flat, gray-colored, crawfishy type. All of these types are naturally very poor in phosphoric acid, lime, potash and nitrogen. Without the aid of phosphate the profitable production of general farm crops is very difficult. Liming comes next in importance, and is generally a necessity in order to get clover and the best results with legumes in general. Potash is much less needed than either phosphate or lime, but in field experiments has often been found to increase the yields of hay and of potatoes. Only moderate applications are needed, however. The nitrogen supply is at best insufficient and in parts quite low.

Although these soils are rated among the poorest in the State, they are, when properly fertilized, adapted to a large number of both farm and

Digitized by Google

garden crops. Dark-leaf tobacco has proved to be a profitable crop and its culture is being extended. Peanuts on a commercial scale may be grown profitably. Perhaps no other part of the State is better adapted to the production of cowpeas for seed. This is due to the fact that by the aid of fertilizers cowpeas fruit abundantly on these soils, without producing an excessive growth of vine. There is some opportunity also for the developing of orcharding and small fruit culture.

Overflow and bench lands.—The overflow and bench soils of the Highland Rim are well suited to cultivation. They are generally highly productive corn lands and are much superior to the uplands in fertility. In Perry and Humphreys counties in particular, the lowlands have been used extensively for peanut production, and are rated of high value.

WEST TENNESSEE.

Uplands.—West Tennessee slopes gradually from the Highland Rim on the east to the Mississippi River on the west. The elevation above sea level varies from 400 to 600 feet. For the most part the surface is gently undulating, and the hilly sections are characterized by lower and more rounded hills than those found in the other parts of the State. Nearly all of the soils are derived from geological deposits which were never consolidated into rock. Most of them are silt loams containing no gravel. Naturally they were well supplied with all of the elements of plant food, but under cultivation they have, with some exceptions, become poor in nitrogen and humus. This result has come about partly by the kind of

FIG. 5. West Tennessee landscape.

Digitized by Google

farming generally followed, and partly because the soils wash badly during heavy rains. In fact no large area in the State has suffered from erosion so much as this. In color the upland soils vary from a light red to gray and brown.

In the writer's opinion the soils of no other division of the State are in general so well adapted to a great range of farm and garden crops or so responsive to judicious treatment as these.

The loess soil.—Perhaps one-fourth of the total area of West Tennessee is covered by a loess formation, which extends in a belt 20 to 25 miles wide, across the western end of the State and parallel with the general course of the Mississippi River. The soils are brownish loams, which lie well for agricultural purposes, are readily tilled, and are adapted to all crops. A rather high content of silt characterizes these soils, which are of great natural strength and fertility. Even after long cultivation in cotton and corn, with the attendant loss by erosion, and with little regard to crop rotation, manuring, etc., profitable crops are obtained. In the improvement of such lands, liming and the production of legumes, the clovers in particular should receive special attention.

The Lagrange soils.—The Lagrange formation covers about one-third of West Tennessee, and occupies a belt 35 miles wide next to and parallel with the loess formation. The major portion of this area is gently undulating, but hilly areas are prominent. The soils of the latter are thinner and have suffered more from erosion than the former.

The typical soil is a grayish-brown silt loam with a yellowish-colored subsoil. Considerable variation is not uncommon on the same farm, for the grayish-brown loam is often replaced, especially on the lower levels, by a gray-colored, very silty soil, resembling in general appearance the "crawfishy" soils of Middle and East Tennessee. Both of these types have been the subject of investigation at the West Tennessee Agricultural Experiment Station at Jackson, and both have been found to be well supplied with phosphoric acid and potash. The grayish-brown loam was found to be very poor in lime, by the adding of which excellent crops of clover and alfalfa were obtained, while without it they were complete failures. This type was naturally very fertile, but long cropping in cotton and corn, together with the attendant erosion, which is more serious than for the loess soils, have greatly reduced the productiveness. However, the readiness with which it responds to good treatment is very striking.

The gray "crawfishy" soils have proved to be considerably superior to soils of similar appearance found elsewhere in the State. Their chief drawback comes from the ease with which the surface soil grains cement

Digitized by Google

together during heavy rains, so that the excess of water is not readily absorbed and the drainage is apt to be poor. On the Jackson farm this type has proved to be very little in need of lime or of any other mineral element. Excellent crops of Japanese clover, peanuts, red clover and alfalfa were obtained with little difficulty. In contrast with the good supply of the minerals, the nitrogen and humus supplies are very low. This kind of soil therefore is not well suited to grain crops, and non-legumes in general, but may be used to much advantage both for pastures and for the production of legumes.

FIG. 6. West Tennessee Experiment Station.

Another common type of soil is reddish-colored. It is said to be by nature fully the equal of the grayish-brown loam. No experimental work has, however, been done on this soil by the Station, so that its specific mineral plant food requirements are not known to the writer. This type is light, easily tilled and contains more sand than the grayish-brown loams. It is suitable to all common farm and garden crops, but erodes very easily, so that it is apt to become poor in nitrogen and humus.

Miscellaneous soils of the eastern section of West Tennessee.—The remaining undescribed portion of West Tennessee, or about one-third of the whole, extends in a somewhat triangular belt across the State from north to south, and borders the Tennessee River in its flow to the north. The width of this belt on the Mississippi line is about sixty miles and on

Digitized by Google

the Kentucky line about fourteen miles. Eight geologic formations are represented within this area, but the major portion of it is covered by only four, which run in narrow parallel belts across the State.

Although there is considerable variation, the soils of this section are in general not equal for agricultural purposes to those of the loess and Lagrange areas. For the most part, they are silt loams of fair natural fertility and suited to the usual crops of the climate; but much of the area has suffered very severely from erosion and the continued production of cultivated crops. Much of the county is hilly and the eastern edge is a continuation of the Highland Rim of Middle Tennessee. The specific plant food requirements of the various soils have not been worked out, but both liming and phosphating are apt to be beneficial, and the need of increased supplies of nitrogen and humus is evident. Considerable areas are better suited to pasture and timber than to cultivated crops.

Bottom and bench lands.—Overflow lands in West Tennessee are comparatively little used for farming purposes, the major part being in timber. The reason for this condition, which is so different from that found elsewhere in the State, is that special drainage systems are necessary in order to warrant cultivated crops. The overflow lands form fairly wide margins along the streams, the channels of which are not large enough in this gently sloping country to carry off the surplus waters from the large areas drained. In addition, while the bottom lands are richer than the neighboring uplands, they do not as a rule have the high fertility of the bottom lands of the other sections of the State. Rather large areas of gray-colored silty soils occur, and where the leaves and other loose material have been swept away from year to year by the floods the soil may be very deficient in humus matter.

These bottom lands are valuable chiefly for their timber, but in addition furnish some grazing for cattle. State laws are favorable to comprehensive drainage projects which have been carried out successfully in some counties, and are in progress in others. The increased value of the reclaimed lands for pasture purposes alone is probably worth all the expense incurred by drainage. Also a considerable portion makes highly productive land for the usual farm crops.

Along the Mississippi River there are some alluvial lands of very great fertility, comparable with the best found anywhere in the world. All the common crops are grown, including alfalfa, which thrives without attention to either liming or manuring.

In the northwestern part of West Tennessee, especially in Obion County, occur rich valley lands which are very durable under cultivation. The soils are dark-colored silt loams and have a moderately high content of humus. For the most part they require tile drainage. These soils are excellent for

Digitized by Google

corn, clover and grass, and also for alfalfa. They appear to be fairly well supplied with all of the plant food elements, even alfalfa being grown to some extent without liming. However, liming is apt to give increased yields of alfalfa and frequently its need is indicated by the litmus test. In no other part of the State is red clover so common and successful a crop, and as long as this is the case profitable crops of all kinds may be expected.

REFERENCES TO LITERATURE ON TENNESSEE SOILS.

The publications from the Agricultural Experiment Station of the University of Tennessee, Knoxville, are as follows:

MOOERS, C. A.

1. Experiments with fertilizers and farm crops on important soil types of Middle Tennessee.
   Bulletin 92 (1911).

2. Fertility and crop experiments at the West Tennessee Station.
   Bulletin 109 (1914).

3. Liming for Tennessee soils.
   Bulletin 97 (1913).

4. The rational improvement of Cumberland Plateau soils.
   Bulletin 101 (1913).

5. The rational improvement of Highland Rim soils.
   Bulletin 102 (1913).

6. The soils of Tennessee, their chemical composition and fertilizer requirements.
   Bulletin No. 4, Vol. XIX (1906).

VANDERFORD, C. F.

The soils of Tennessee.
Bulletin No. 3, Vol. X (1897).

The following articles have appeared in the "Resources of Tennessee:"

MADDOX, R. S.

West Tennessee gullies, lands and their reclamation.
Vol. V, No. 1, January, 1915.

PURDUE, A. H.

The gullied lands of West Tennessee.
Vol. III, No. 3, July, 1913.

ROGERS, REESE F.

The soils and agricultural resources of Robertson County.
Vol. II, No. 12, December, 1912.

Digitized by Google

The Bureau of Soils of the U. S. Department of Agriculture has published reports of surveys as follows:

Clarksville area	published in ——
Coffee County	published in 1910
Davidson County	published in 1904
Giles County	published in 1909
Grainger County	published in 1907
Greeneville area	published in 1904
Henderson County	published in 1905
Jackson County	published in 1915
Lawrence County	published in 1905
Madison County	published in 1907
Overton County	published in 1909
Pikeville area	published in 1904
Putnam County	published in 1914
Robertson County	published in 1914
Sumner County	published in 1910

Digitized by Google

Recent Oil Developments Near Oneida, Scott County, Tennessee

By L. C. Glenn.

INTRODUCTION.

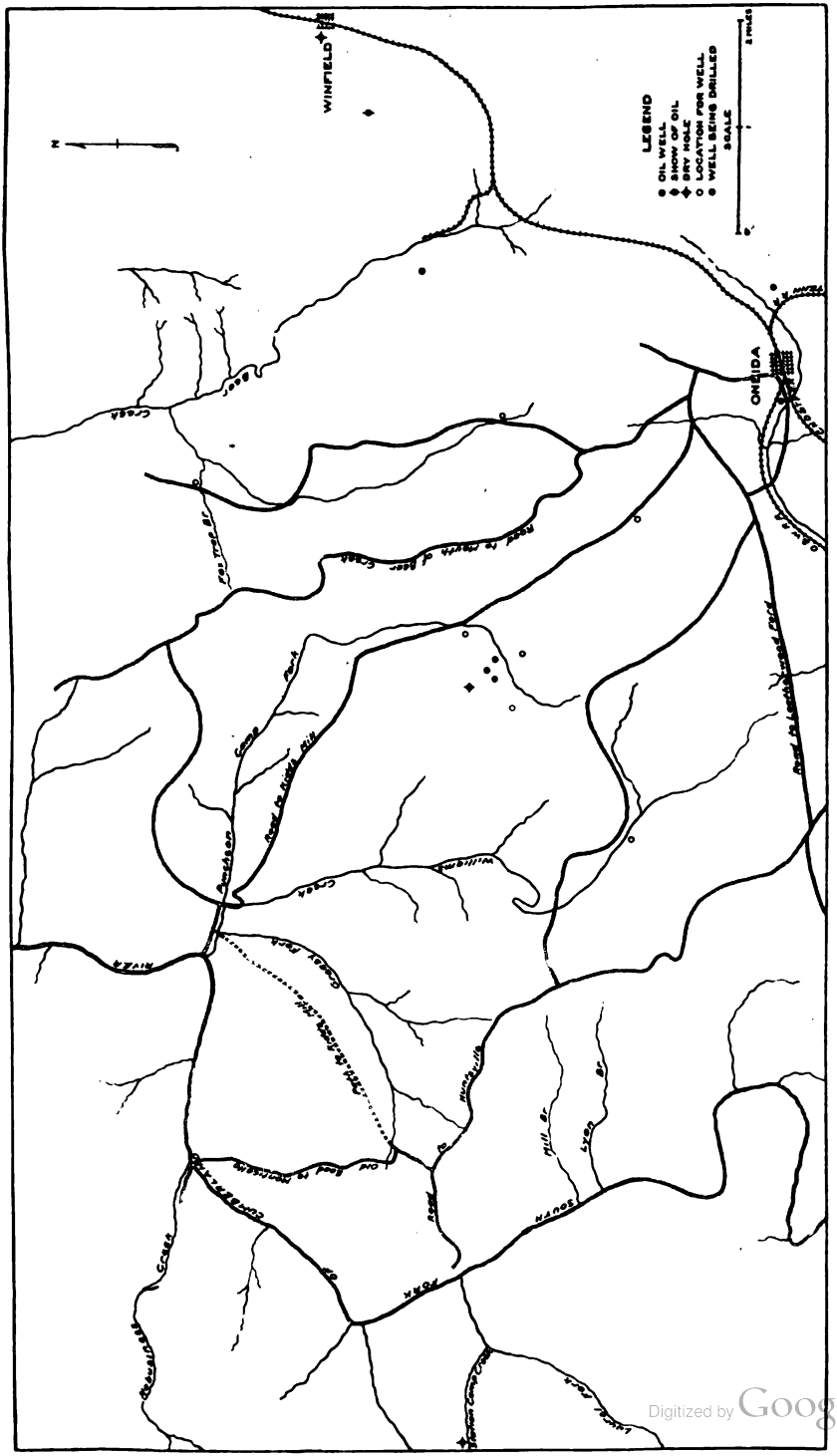
Location.—Scott County is situated on the northern part of the Cumberland Plateau and has the Kentucky State line as its northern boundary. Oneida is in the north-central part of the County on the C., N. O. & T. P. railroad, and the recent oil developments have been about four miles northwest of town. Two wells are now drilling in town and a number of other locations have been made especially to the north and west of the town, as may be seen from the accompanying map, Fig. 1. Some of these located wells will probably be drilling and other locations will doubtless have been made before this report is published.

Basis of report.—The work of the writer, for the past few summers, on the coals of the northern part of the Cumberland Plateau has made him familiar with the general geology of Scott County and the adjacent region. In June a week was spent in the field studying the geology with especial reference to the occurrence of oil and a second visit was made to the field in mid-August. Mr. Henry F. Bain was employed to collect samples of the borings from the West No. 1, Toomey No. 2 and Hendren No. 1 wells. The accompanying logs and plotted sections of these three wells have been made from these samples, while the logs of Toomey No. 1 and Easter No. 1 wells have been taken from the drillers' records.

The materials collected by Mr. Bain have been carefully studied and compared with each other by the writer and chemical analyses of certain of the "sands" have been made by Dr. Bowers in the laboratory of the Survey. Analyses of the oil have been made both by Dr. Bowers and by the U. S. Bureau of Mines.

Acknowledgments.—The writer is especially indebted to Mr. Chas. W. Whitcomb, Mr. J. P. Hambrick, the Syndicate Oil and Gas Company, and the drillers of the three wells, sampled by Mr. Bain, for drillers' logs and facilities and aid in collecting samples as well as for much general information as to activities in the field. He is also greatly indebted to Mr. Bain for the care with which the samples were collected.

Digitized by Google


WINFIELD
ONEIDA
LEGEND
OIL WELL
SHOW OF OIL
DRY HOLE
LOCATION FOR WELL
WELL BEING DRILLED
SCALE
1 MILE
N
Creek
Pond
Creek
Creek
Creek

DEVELOPMENTS.

Drilling was started on the first well, the Toomey No. 1, on February 20, 1915, and it was completed to a depth of 1700 feet on April 27. The West No. 1 well was drilled June 12 to July 7 to a depth of 1100 feet; the Hendren No. 1, June 21 to July 13, 973 feet deep; and the Toomey No. 2, July 3 to 23, 965 feet deep. These wells are all in a group some four miles northwest of Oneida, their location with reference to each other being shown in Fig. 2.

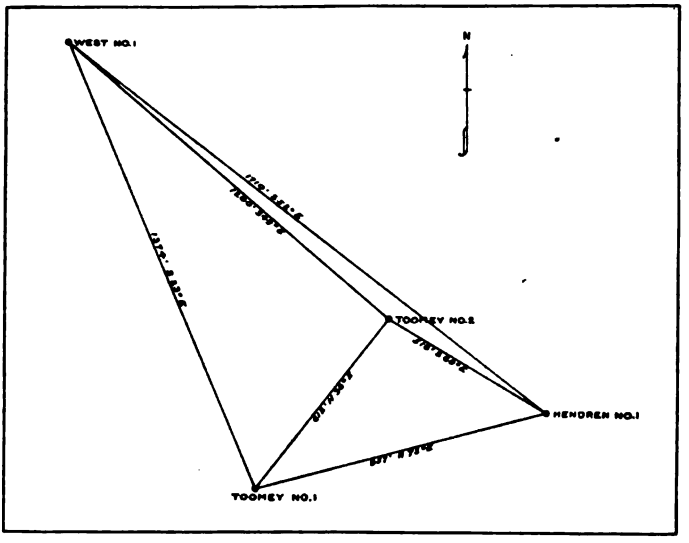


FIG. 2. Location of Toomey 1 and 2, West 1 and Hendren 1 oil wells.

WELL RECORDS.

Record of Toomey No. 1 well, 4 miles northwest of Oneida, Tenn.

Drilled by Chas. W. Whitcomb; elevation 1320 feet. Well mouth about 220 feet below the top of the Lee formation. Diameter at mouth 8¼ inches; placed 8¼-inch casing at 335 feet, 6¼-inch casing at 788 feet.

	Thickness	From	To
Soft dark sand	20	0	20
Hard white sand	180	20	200
Hard dark slate and thin coal	30	200	230
Hard white sand	80	230	310
Soft slate	40	310	350
Hard white sand	70	350	420
Soft slate	10	420	430
Slate, alternately hard and soft	120	430	550

Digitized by Google

	Thickness	From	To
Hard white sand (base of Lee)	60	550	610
Soft red slate, caving (Pennington)	140	610	750
Hard gray limestone (top of Newman)	195	750	945
Gray limestone, sandy, fairly soft—the oil "sand"	20	945	965
Gray and brown limestone, mostly hard	331	965	1296
Soft blue slate	10	1296	1306
Dark gray limestone, hard and gritty	71	1306	1377
Pinkish crystalline limestone	19½	1377	1396½
Very hard gray limestone with dark specks	2	1396½	1398½
Very hard limestone, color varying	19½	1398½	1418
Hard white limestone	12	1418	1430
Hard limestone, brownish (Beaver?)	45	1430	1475
Soft black shale (Chattanooga shale)	65	1475	1540
Soft bluish-gray shale (Osgood?)	15	1540	1555
Soft blue limestone with thin layers of shale	45	1555	1600
Hard blue limestone (Clinton or Hudson?)	35	1600	1635
Grayish blue limestone, alternately hard and soft (Hudson?)	65	1635	1700

The following records are based primarily on the study of the borings collected by the Survey, but are supplemented by the drillers' logs.

Record of West No. 1 well, 4 miles northwest of Oneida, Tenn.

Drilled by Chas. W. Whitcomb; elevation 1357 feet; well mouth about 180 feet below the top of the Lee formation. Diameter of well mouth 10 inches; placed 8¼-inch casing at 348 feet and 6¼-inch casing at 889 feet.

	Thickness	From	To
Surface material	45	0	45
Hard blue sandy shale	30	45	75
Dark sand-shale	5	75	80
White sandstone	94	80	174
Silty sandstone and leaden shale	11	174	185
White sandstone	11	185	196
White sandstone with dark shale partings, a sand-shale	6	196	202
Blank—probably sandstone	8	202	210
Sandstone	120	210	330
Thinly laminated sandstone, shale partings	11	330	341
Dark sandy shale	21	341	362
Blank—probably sandstone	6	362	368
Sandstone	97	368	465
Blank—probably sandstone	23	465	488
Laminated sandstone with dark shale partings	5	488	493
Blank—probably shale	6	493	499
Dark shale	5	499	504
Sandstone	33	504	537
Dark laminated sand-shale	19	537	556
Dark shale	5	556	561
Thin laminated sandstone with dark shale partings	33	561	594

Digitized by Google

	Thickness	From	To
Fine white sandstone	5	594	599
Dark shale (base of Lee)	6	599	605
Limestone (top of Pennington)	5	605	610
Red, green and dark shales	89	610	699
Red and green shale with some limestone	6	699	705
Shales, dark slate colored	16	705	721
Blank (shales)	6	721	727
Red, green, and dark slate-colored shales	7	727	734
Red and green shales	42	734	776
Dark shales	18	776	794
Dark shale and light gray limestone	6	794	800
Red, green and dark shales	40	800	840
Gray limestone	8	840	848
Brown, sandy limestone, oil-bearing	5	848	853
Gray limestone with shale probably from caving	15	853	868
Oölitic limestone	10	868	878
Dark gray limestone, some dark and red shale partings	52	878	930
Limestone, brown and dark gray, crystalline	65	930	995
Brownish gray, compact, fine-grained limestone	45	995	1040
Brownish-gray crystalline limestone	15	1040	1055
Brownish-gray, compact, fine-grained limestone	17	1055	1072
Brownish-gray, crystalline limestone	6	1072	1078
Light gray crystalline limestone	6	1078	1084
Brownish-gray crystalline limestone	16	1084	1100

Record of Hendren No. 1 oil well, 4 miles northwest of Oneida, Tenn.

Drilled by Chas. W. Whitcomb. Elevation 1298 feet; mouth of well about 240 feet below the top of the Lee formation; diameter at well mouth 8¼ inches; 8¼-inch casing to 335 feet; 6¼-inch casing to 788 feet.

	Thickness	From	To
Sandstone	205	0	205
Dark shale	5	205	210
Sandstone	12	210	222
Sandstone, with some black shale	5	222	227
Sandstone, with occasional coal particles	58	227	285
Dark shale	20	285	305
Dark sandy shale and fine sandstone	15	305	320
Dark shale	15	320	335
Blank	6	335	341
Sandstone, water at 374	61	341	402
Dark shale	22	402	424
Sandstone, with some sandy shale partings	60	424	484
Dark shale	6	484	490
Dark, laminated sandstone	5	490	495
Dark shale, part sandy	11	495	506
Laminated sandstone	5	506	511

Digitized by Google

	Thickness	From	To
Sandstone with shale partings, signs of coal near bottom	20	511	531
Blank—probably sandstone	23	531	554
Sandstone (base of Lee)	6	554	560
Red and green shale (top of Pennington)	28	560	588
Red and green shale, with some limestone	6	588	594
Red, green and dark shale	48	594	642
Red and dark shales and some dark limestone	6	642	648
Dark limestone, fine-grained	7	648	655
Red and dark shales, with thin limestones at 676 and 697	93	655	748
Light gray limestone	3	748	751
Dark shale	6	751	757
Dark limestone	7	757	764
Dark and red shale	6	764	770
Dark limestone	40	770	810
Gray limestone with some fine gray siliceous dolomite.	5	810	815
Gray limestone	11	815	826
Oölitic limestone	6	826	832
Dark crystalline limestone with some gas at 845 and some dark shale at 881	83	832	915
Gray crystalline limestone with some dark shale with show of oil at 930	25	915	940
Very compact brownish limestone, with lower half as top of oil "sand"	10	940	950
Brownish and gray finely granular limestone, with some shale partings (or caving?), with oil "sand" down to 968	23	950	973

Record of Toomey No. 2 oil well, 4 miles northwest of Oneida, Tenn.

Drilled by the Syndicate Oil and Gas Company. Elevation 1352 feet. Well started about 190 feet below the top of the Lee formation. Diameter at mouth 10¼ inches; 8¼-inch casing placed at 345 feet; 6¼-inch casing at 800 feet.

	Thickness	From	To
Surface materials	12	0	12
Soft shale and blue clay	5	12	17
Laminated sand and dark shale, mixed	29	17	46
White sandstone, with dark sand-shale at 217-224	199	46	245
Dark sandy shale	5	245	250
White sandstone	89	250	339
Dark sandy shale with some thin sandstone	56	339	395
White sandstone with occasional thin shale partings	71	395	466
Dark sandy shales	17	466	483
Light and dark gray sandstone	19	483	502
Dark sandy shale	13	502	515
Gray sandstone	41	515	556

Digitized by Google

	Thickness	From	To
Dark shale	6	556	562
Dark gray sandstone	6	562	568
Dark shale	6	568	574
Sandstone, with some dark shale (base of Lee)	40	574	614
Gray limestone (top of Pennington)	14	614	628
Red and green shale, with thin limestone at 717	107	628	735
Dark slate-colored shale	14	735	749
Red and green shale	56	749	805
Light gray limestone	10	805	815
Dark shale with occasional thin limestone	45	815	860
Brown saccharoidal dolomite, fine-grained, oil-bearing	5	860	865
Dark limestone, and some brown dolomite	5	865	870
Dark limestone	5	870	875
Oölitic limestone	5	875	880
Dark gray limestone	65	880	945
Fine brown dolomitic limestone, saturated with oil, had some gas	5	945	950
Fine dark-gray limestone	5	950	955
Brownish-gray crystalline limestone with top of oil "sand" reached at 960	10	955	965

Correlations.—While the general geology will be discussed on a later page, it may be well to point out here certain correlations in the above records.

In each well a number of the samples above the first red shale, or first plainly evident limestone, were tested chemically for limestone so that the boundary between the Lee and the Pennington is fixed with certainty. In the Toomey No. 2 and the West No. 1 wells the top of the Pennington is limestone, but in the Hendren No. 1 well it is red and green shale.

Beneath about 200 feet of Pennington shale there appears in each of the three wells a very light gray or almost white limestone that must be at the same horizon. Between 50 and 60 feet lower in the Toomey No. 2, at a depth of 860-865, and in the West No. 1 at 848-853 depth there appears a very fine-grained saccharoidal brown magnesian limestone (see analysis No. 2), that is undoubtedly the same in each well. This bed is very inconspicuous in the Hendren No. 1 well, but it is believed that it is represented by some fine gray material, not oil-bearing, at 810 to 815.

In each well an oölitic limestone appears ten or fifteen feet below this fine magnesian limestone. In the Hendren No. 1 well it is found at 826 to 832, in the Toomey No. 2 at 875 to 880, and in the West No. 1 at 873 to 878. The position of these different beds is indicated in the columnar sections in Fig. 3, and their importance will become obvious in the discussion of the structure on a later page.

Digitized by Google

WELLS DRILLING.

At Oneida the Easter Oil and Gas Company's well No. 1 began drilling August 3. It is located about a half mile southeast of town at an elevation of 1481 feet. The well mouth is 80 or 90 feet above the top of the Lee formation, though the following log, as given by the drillers, fails to note the sandstone that forms the top of the Lee. This sandstone is struck in water wells in town at a depth of 20 to 40 feet, and in the water well at the Oneida and Western Railway shops it was penetrated to a depth of 90 feet without reaching bottom. It is possible, though hardly probable, that this thick sandstone has changed to shale in the three-fourths of a mile interval between the two wells. The depth to the Almy or Bear Creek coal was not definitely noted in the Easter well, but was given as "somewhere about 90 feet." This coal crops out in the south edge of town and should be only about 50 or 60 feet deep in the well.

Record of Easter Oil and Gas Company's well No. 1 at Oneida, Tenn.

	Thickness	From	To
Soft gray shale, with 12-inch coal at about 90 feet (probably 50 or 60 feet instead)	300	0	300
White sandstone	55	300	355
Black slate	35	355	390
White sandstone	70	390	460
Black slate	20	460	480
White sandstone	45	480	525
Black slate	5	525	530
White sandstone	120	530	650
Black slate	5	650	655
Sandstone with water	40	655	695
Coal (and shale?)	5	695	700
Hard black slate	30	700	730
Soft black shale	145	730	875
Hard black slate and sand	10	875	885
White sandstone	15	885	900
Soft black slate	55	900	955
White sandstone (base of Lee)	35	955	990
Limestone (top of Pennington)	10	990	1000

In addition to the foregoing well, another, the Anderson No. 1, is being drilled in the western edge of Oneida by the Oneida Oil and Gas Company. This one was down only a few hundred feet in the Lee formation when visited and so no record was obtained.

Digitized by Google

WELLS LOCATED.

A number of other locations have been made and in mid-August preparations for drilling were being made. The position of these future wells may be seen from the accompanying map, Fig. 1.

WELLS DRILLED IN ADJACENT TERRITORY.

A number of wells have been drilled in adjacent territory, brief reference to which would seem desirable here.

Winfield well.—This well was drilled in 1905 on the L. E. Bryant property at Winfield, some 250 yards west of the depot. Its elevation is about 1343 feet, and the mouth of the well is just about the top of the Lee formation. The record as given by Munn* is as follows:

Record of Bryant well, Winfield, Tenn.

Coal No. 3, at 100 feet; Coal No. 1, 5 feet, at 525 feet.

	Thickness	From	To
(Lee formation)	900	0	900
Pennington shale	90	900	990
Newman limestone	375	990	1365
Sandstone(?) (Newman limestone and Waverly)	300	1365	1665
Chattanooga shale	38	1665	1703
Limestone and shale to bottom	507	1703	2210

This well is reported to have gotten a sand at about 900 feet that was thought would yield a 9 to 12 barrel well. In the Beaver sand close above the Chattanooga shale some oil and gas were found and the well was shot there. After deepening to 2210 feet the well was abandoned.

The Shoally Fork or Jones well.—This well was drilled about 1899 by the Hydetown Oil and Gas Company, about 1½ miles southwest of Winfield. Its elevation is about 1378 feet and the well mouth is within a very few feet of the top of the Lee formation. The record given to the writer from memory by Mr. L. E. Bryant is as follows:

Record of Shoally Fork Well, Scott County, Tenn.

	Thickness	From	To
Sandstone	175	0	175
Thin coal (No. 3½?)	...	....	....
Sandstone	375	175	550
Coal (No. 3), reported	3 or 4	550	553
Sandstone with oil	110	553	663
Thin coal (No. 2½?)	...	....	....

*Bull. 2-E, Tenn. Geol. Survey, p. 20.

Digitized by Google

This lower sand was estimated to yield from 2 to 10 barrels per day. On deepening the well, salt water was encountered, and on reaming out the hole to reset the casing a string of tools was lost and the well abandoned.* Another report gives the total depth of this well as 624 feet.

Bear Creek well.—This well was started late in 1914, about four miles a little east of north of Oneida at the Bear Creek mines, but difficulties were experienced and work was stopped at a depth of 580 feet, the entire distance being in the Lee formation. The well mouth has an elevation of about 1450 feet and is at the top of the Lee formation.

Beatty well.—This well, located on the Big South Fork of Cumberland River, 2 or 3 miles north of the State line in Kentucky, was drilled about 1825 for brine. Its elevation is about 815 to 825 feet, and the top is in the Pennington shale, probably between 25 and 75 feet below the top of this shale. One report says oil in considerable quantities was encountered at a depth of about 200 feet, while another account says oil was struck 350 or 360 feet down. It is understood that this old well is to be cleaned out. A short distance west of it several wells located on the plateau surface some 500 feet higher have just been drilled and are said to have made satisfactory showings. The same parties are continuing their drilling in that region. Their wells on the plateau level are about 500 feet above water level in the river. They reach the base of the Lee at about 380 feet, get the top of the big lime (Newman) about 675, get the first pay "sand" at 700, and others at 800, 900 and 956 feet in the big lime, with the Chattanooga black shale at 1290 feet depth.

Owens well on Station Camp Creek.—This well was drilled by Cadahy Bros. of Chicago in 1896 about 1½ miles west of the South Fork of the Cumberland River on Station Camp Creek. It started in the sandstones of the Lee formation, not far above their base. Salt water was found at various depths from 200 to 550 feet. The Beaver sand, extending from about 600 to 750 feet depth, was very hard and flinty and made a small showing of oil. The total depth reached was 1515 feet when the well was abandoned.

Rugby Land Company well No. 1.—This well was drilled in 1896 by the Forest Oil Company, in the extreme southwestern edge of Scott County, a few miles northwest of Rugby Road. The well was started at an elevation of 1280 feet. There was a show of tar at 512-517 in hard white sand, and a show of dark green oil in hard white lime at 1335-1340. The detailed log given by Munn† may be briefly summarized here as follows:

*Munn, *op. cit.* p. 20.
†*Op. cit.*, p. 20.

Digitized by Google

Condensed record of Rugby Land Company Well No. 1.

	Thickness	From	To
Briceville shale	60	0	60
Lee formation	702	60	762
Pennington formation	208	762	970
Newman limestone (and Waverly?)	713	970	1683
Chattanooga black shale	45	1683	1728
Silurian (?) and Ordovician limestone and shale	673	1728	2401

Rugby Land Company well No. 2.—This well was drilled in 1896 by the Forest Oil Company in the extreme northern part of Morgan County and about 1½ miles south of Rugby. The well was started some 150 to 200 feet below the top of the Lee formation. A show of green oil was found in a reddish-brown sand in the Newman limestone at 1215 to 1230. The detailed log given by Munn * may be condensed as follows:

Condensed record of Rugby Land Company well No. 2.

	Thickness	From	To
Lee formation	525	0	525
Pennington formation	235	525	760
Newman (and Waverly?)	695	760	1455
Chattanooga black shale	40	1455	1495
Silurian (?) and Ordovician limestone and shale	1298	1495	2793

TOPOGRAPHY.

Drainage.—The region about Oneida is drained westward and northwestward into the Big South Fork of Cumberland River by a number of small creeks whose headwaters flow at about the general country level and are apt to have sluggish currents and to be bordered by swampy flood plains. The middle and lower courses of these streams, however, have cut below the general level of the upland surface and flow in rough canyons walled in by massive sandstone cliffs.

The river flows in a narrow canyon-like valley, a fourth to a half mile wide, cut some 500 to 600 feet below the general upland surface. The sandstone cliffs along its sides are in places 300 or 400 feet high, as for example near the mouth of Pine Creek.

Surface relief.—The region may be divided into two parts on the basis of differences in surface relief. North and west of Oneida, the country is a rolling plateau, whose surface—some 1400 to 1600 feet above sea level—is broken along the middle and lower courses of the streams by the deep and narrow gorges in which they flow. These stream gorges are usually rimmed with sandstone cliffs and their steep sides are often strewn with

*Op. cit., pp. 22-23.

Digitized by Google

large boulders. These gorges are several hundred feet in depth and are serious obstacles to any travel across them. The few roads in the region keep as much as possible up on the plateau surface and usually follow the divides between the main streams.

To the south and east of Oneida, the plateau-like character is largely lost and the country becomes hilly to mountainous, often with steep slopes and narrow stream valleys, but usually without the rugged character of the cliff-bound stream gorges of the more westerly plateau portion.

The Queen and Crescent Railway may almost be taken as the dividing line between the two types of surface, since the hilly region to the east and southeast of this road extends west of it in but a few places and for short distances only. Most of the region is wooded. Farms, especially on the plateau part, are few and small.

GEOLOGY.

The rocks of the region consist of sandstones, shales and limestones that are grouped into a number of formations, the three youngest of which are exposed at the surface either in the vicinity of the wells or a few miles west of them in the bottom of the lower courses of the larger stream gorges and along the Big South Fork River. Several of the older formations reached by the drill do not appear at the surface in this immediate region, but are well known as surface formations both east and west of here.

SURFACE FORMATIONS.

Briceville shale.—The youngest rocks of the region that have been penetrated by the drill so far are a series of soft shales with subordinate sandstones, known as the Briceville shale. These rocks form the surface of the hilly or southeastern portion of the region as above described. About 30 or 40 feet above their base they contain a coal that has been mined at Helenwood, Almy, Bear Creek and elsewhere. West of Oneida these shales remain mostly in more or less isolated patches that disappear entirely in a few miles to the west of town and leave the surface composed of the rocks of the next underlying formation, which is known as the Lee. To the east of Oneida, the Briceville shales are overlaid on the higher peaks and ridges by later formations that, like the Briceville, are also of Pennsylvanian age.

Lee formation.—Immediately under the Briceville shale there come a series of sandstones and shales some 700 to 900 feet thick known as the Lee formation. The sandstones are usually massive and in places are conglomeratic. The shales are subordinate in amount and generally dark gray to almost black in color. At several places the drillings show parti-

Digitized by Google

cles of coal, though in the Toomey-West-Hendren group of wells, it was not certain that the coal was of commercial thickness. In the Easter well several feet of coal were found at a depth of 695 feet. In detail, the thickness of the individual beds of sandstone and shale vary rapidly so that sections made at even short distances apart may fail to match except in a broad general way. Examples of such variation may be seen in the plotted sections given in Fig. 3. The total thickness of the Lee formation at the group of wells four miles northwest of Oneida varies from 785 to 804 feet for the three wells whose cuttings were examined by the writer. In the Toomey No. 1 the thickness as deduced from the driller's record is 830 feet. To the east the Lee is known to thicken considerably and in the Easter well at Oneida it is 900 feet or slightly more in thickness. To the west it becomes gradually thinner. The Lee forms the base of the Pennsylvania or Upper Carboniferous.

Pennington shale.—The top of this formation is marked either by a few feet of limestone or by red and green shales. The top of these shales is soft and often gives the drillers trouble by caving. In them there are occasional thin beds of limestone and in their middle and lower parts much of the shale is dark slate colored and breaks into long prismatic or pencil-like pieces. The thickness of the Pennington in the Hendren well is 188 feet, in the West well 189, and in the Toomey No. 2, 191. In the Rugby Road and Rugby wells it is 208 and 220 feet respectively, while in the Winfield well it is reported as only 90 feet.

It is known that after the Pennington was deposited this whole region was uplifted and its surface was subjected to a prolonged period of erosion before it sank again and the materials of the Lee began to be laid down upon it. This erosion doubtless removed more of the Pennington in some places than in others and left its upper surface irregular, and the thickness of the part remaining, variable.

The Pennington appears at the surface only along the Big South Fork River and the lower mile or two of the courses of its principal tributaries.

The Pennington shale forms the top of the Mississippian or sub-Carboniferous in this region.

UNDERGROUND FORMATIONS.

The following formations do not appear at the surface in this immediate vicinity but are encountered in the deep wells.

Newman limestone.—Beneath a considerable interval of red and dark shales there appears in the Oneida region a very light, almost white, limestone that is here taken as the top of the Newman limestone. Beneath it there is a variable succession of limestone and red and dark shale beds

Digitized by Google

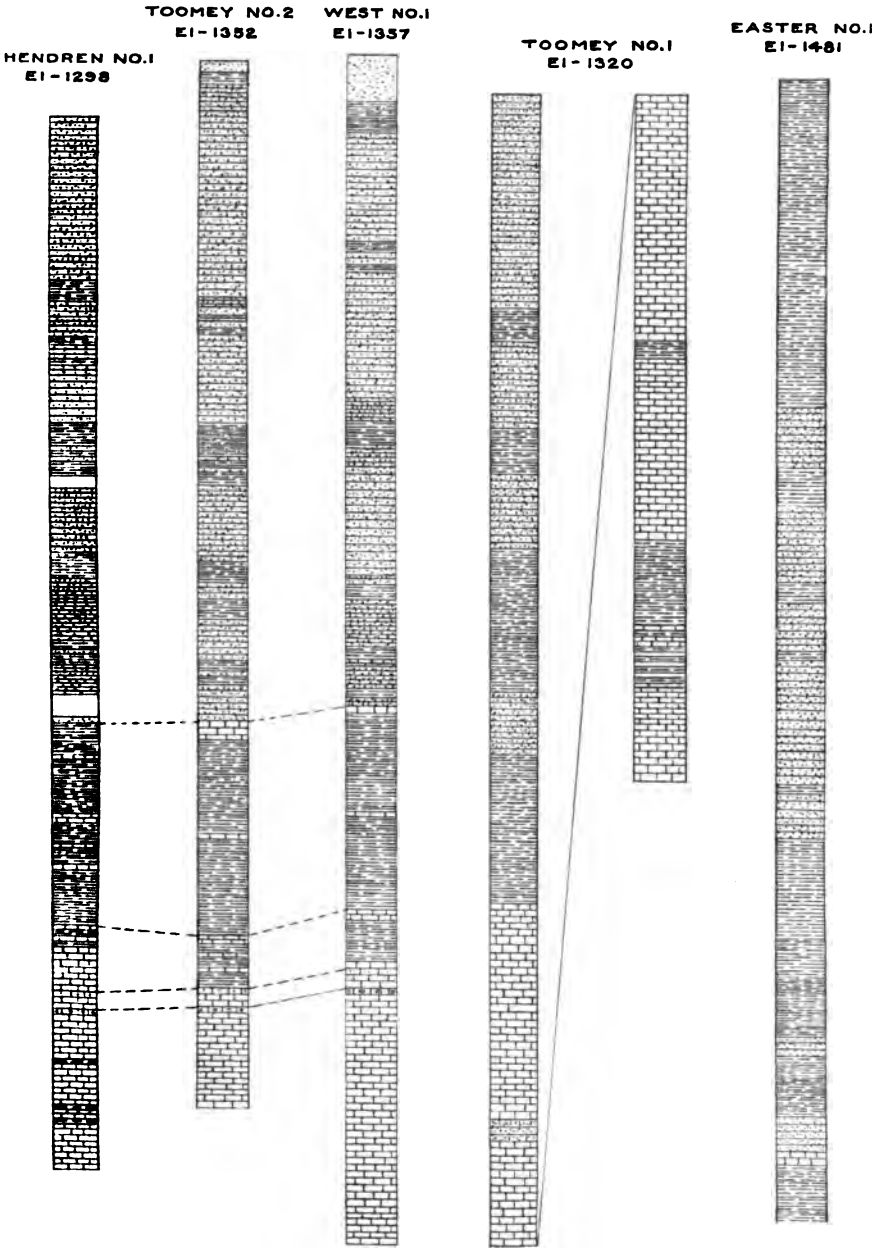


FIG. 3. Sections of oil wells in Scott County. Scale, 1 inch=178 feet.

Digitized by Google

for some 40 or 50 feet, when more massive limestone appears and continues down for more than 600 feet. At the top, this massive limestone may show a few feet of brown oil-bearing dolomite, as in the West No. 1 and Toomey No. 2 wells, and some 10 to 20 feet below it there are a few feet of gray oölitic limestone. Lower in the section some hard cherty material is found and some thin shales may appear, but from the records no distinct separation of the material down to the Chattanooga black shale seemed possible, though it is probable that the lower part of what is here grouped together as the Newman limestone is the equivalent of the Waverly. Parts of this limestone are more or less magnesian or dolomitic, while other parts are very dense and fine-textured. The horizon of the Beaver "sand" occurs in the lower part of this long limestone interval, but was not found to be oil-bearing in the Toomey No. 1 well. The total thickness of the Newman, or Newman-Waverly, in that well was 725 feet, while in the Winfield well it is 675 feet, in the Rugby well 695, and in the Rugby Road one 713 feet. It is the oldest of the Mississippian or sub-Carboniferous formations.

Where the Newman limestone rises to daylight in Overton and Fentress counties some 35 to 50 miles west of this region, it contains a sandstone lentil about 150 feet from the top, that was at first thought would prove to be the oil-bearing member in this Oneida region, but the chemical analysis of the oil-bearing rock given on a succeeding page makes it certain that it is either a pure or a dolomitic limestone. The horizon of the oil "sand" is, however, not far from the horizon of the sandstone lentil.

Chattanooga black shale.—This is a homogeneous fine-grained black shale, of Devonian age, that is reached in only the deeper wells of the region. It is so different in color and character from the materials above or below that it is very easily recognized and serves as an excellent horizon marker. It seems to vary from 40 to 65 feet in thickness in the few well records available.

Silurian and Ordovician rocks. — Beneath the Devonian black shale there is a long succession of blue and gray limestones and shales as recorded in the records of the Toomey No. 1 and the Rugby Road and Rugby wells. There is very little in these records, however, upon which to base an opinion as to what part may be Silurian and what Ordovician in age. The soft shale just beneath the Chattanooga black shale may belong to the Osgood formation of the Silurian and the hard blue limestone below it may either represent the Clinton and hence be also of Silurian age, or may belong to the Hudson River or Cincinnatian group of Ordovician age. Somewhat farther east at Elk Valley and along the Cumberland front the Clinton contains a red fossil iron ore that should be carefully looked for in wells that penetrate any distance below the Devonian

Digitized by Google

black shale. This red iron ore has not been recorded in any of the wells whose records are given here, but it is present in some deep wells somewhat northeast of this region.

STRUCTURE.

The broad general features of the structure of the region are simple and easily grasped. From a synclinal axis that lies a score or more miles to the east of Oneida and runs northeast and southwest parallel to the general trend of Pine and Cumberland mountains, the rocks rise gently but persistently to the westward for many miles. This westward rise is maintained in fact until the axis of the Cincinnati-Nashville uplift is reached some 50 or 60 miles beyond the western edge of the Cumberland Plateau.

It is not probable that this rise to the west or west-northwest is substantially at a uniform rate, though the evidence to firmly establish this point is lacking at present, largely because, for the region west of Oneida, there are no good maps or well-established bench marks to give elevations that would enable the details of the structure to be readily determined. Some level lines have been run by Mr. Chas. W. Whitcomb from Oneida to his group of wells northwest of town and from these it is shown that the base of the Lee or the top of the Pennington, rises westward between these points at the rate of 40 to 50 feet per mile. Whether the direction between these points is that of the maximum rise for the region can not yet be known, but if not it is probably not far from it.

While the *base* of the Lee rises at the rate of 40 or 50 feet per mile as above given, the *top* of the Lee as traced from Oneida to the Toomey wells does not rise over 30 feet per mile, thus showing that a thickening in the Lee to the eastward occurs either within the body of the formation or, as some prefer to think, at its base. It is hoped that the logs of some of the wells soon to be drilled may throw more light on the way in which this change in the thickness of the Lee occurs, since it bears directly on determining the structure of the rocks beneath the Lee.

The contact between the Lee and the Pennington is marked, as has been stated, by an old erosion surface resulting from a period of uplift and erosion, or as it is generally called, by an unconformity. This unconformity will doubtless add to the difficulties of determining, from the structure of the Lee as revealed at the surface, what the exact structure of the rocks below the Pennington may be, and yet it is believed that the essential features of the structure of these lower rocks may be determined by careful work on the surface rocks.

What secondary structural features may be superposed upon the broad general westward rise of the rocks is not known. It has been thought by

Digitized by Google

some that the rocks in the West No. 1 well indicated that instead of the usual rise of the rocks to the west, there was a reversal of dip between it and the Toomey and Hendren wells, but the logs of these wells as plotted in Fig. 3 fail to bear out this idea, but show instead a westward *rise* of the rocks from the Toomey No. 2 well to the West No. 1 as is consistently indicated by the base of the Lee, the top of the Newman, the brown oil sand and the oölitic limestone, the positions of all of which are given in the figure. The relative positions of these wells are given in Fig. 2. From the Hendren No. 1 well to the Toomey No. 2 there is a slight westward dip that would probably aid in arresting the movement of any oil that might be migrating up the general dip. Unless there is a continuation of this reversed dip east of the Hendren No. 1 well, it would not be sufficient to completely trap the oil, since the reversal shown in these wells amounts to less than the thickness of the oil sand.

In the Wayne County, Kentucky, oil fields there are very plain indications of a secondary structure consisting of a cross wrinkling or corrugation, as it were, with its axes running in the general direction of the dip of the major structure of the region, and such secondary structure may also characterize this region.

There is some evidence from the surface rocks about the Toomey wells, and for a distance of about a mile back toward Oneida that the broad general westward rise of the rocks previously spoken of, has been partially arrested, and that this group of wells, especially the Toomey Nos. 1 and 2 and the Hendren No. 1 have been drilled on a structural terrace.

In some places in this general region a slight doming occurs, as is shown in some coal seams, but no work has been done around these oil wells to show either the presence or absence of a structural dome about them.

THE OIL SAND.

Microscopic examination shows that the oil "sand" is not a sandstone as it was at first thought it might prove to be. The two "sands" that appear porous when examined with a hand lens are the siliceous magnesian limestones at 848 to 853 feet depth in the West No. 1 well and at 945 to 950 feet in the Toomey No. 2 well. The oil "sand" from 946 to 964 feet in the Hendren No. 1 well is almost a pure limestone.

Digitized by Google

The analyses of these samples are given in the following table:

Analyses of oil-bearing "sands."

Well	Toomey No. 2.	West No. 1.	Hendren No. 1.
Depth	945-950	848-853	946-964
Insoluble siliceous matter	16.06	9.09	3.09
Al_2O_3 and Fe_2O_3	4.23	1.97	0.58
$CaCO_3$	61.69	58.77	94.86
$MgCO_3$	16.74	30.09	0.19
Loss	1.28	0.08	1.28
	100.00	100.00	100.00

It is believed that the production in the Toomey Nos. 1 and 2 and the Hendren comes from a jointed or slightly fissured or fractured limestone, either pure or dolomitic. From a comparison of the logs of the Toomey No. 2 and the Hendren No. 1 it seems probable that this fissured oil-bearing limestone is not at exactly the same horizon in the two wells, and that the oil does not come from the same identical beds. The oil-bearing rocks in the Toomey No. 2 well appear to be 40 or 50 feet higher stratigraphically than in the Hendren No. 1 well, and it is possible that if the former well were deepened some 50 feet a second pay might be struck. This fissuring or fracturing is probably not far from the same horizon in neighboring wells, but that it is not universal is shown by the failure to find a pay sand in the West No. 1. It is possible that wells several miles apart may find considerable variation in the stratigraphic horizon at which fissured or dolomitized oil-bearing rocks occur, and until the character and oil-bearing features of these Newman limestones become better known, it would be desirable for future wells that fail to secure oil at about the horizon productive in the Toomey or Hendren wells, to be drilled some 100 or 200 feet deeper to test out the possibility of porous or fissured oil-bearing rocks occurring at a somewhat lower level in the Newman.

Thickness of "sand".—The thickness of the "sand" or "sands", so far as known, is about 20 to 23 feet. In the Toomey No. 1 well it is probable that a few feet below the pay there is a second pay a few feet thick; while in the Toomey No. 2 well ten feet above the main pay, there are five feet of what appears to be a good sand at 945-950.

Water.—The rocks seem to contain comparatively little water. In some of the wells no mention is made of it at all. It is possible that drilling about Oneida or east of there where the rocks are considerably lower may find more water than is found farther west if the strata contain any notable amount of water anywhere.

Gas.—Very little gas has been encountered.

Production.—No adequate tests have been made of the daily capacity of any of the wells as yet. The Toomey No. 1 was pumped from 3 to 9

Digitized by Google

hours on each of eight successive days in May and the production was at the rate of 3 to 7 barrels per hour of pumping. What production steady pumping would yield, it is impossible to say, as tanks have not been provided to take care of the oil. The Hendren well is said to have flowed some 40 barrels in a few minutes shortly after it was drilled in. The writer believes that a conservative estimate for the wells so far drilled would be from 20 to 50 barrels each per day.

Pipe line.—The nearest pipe line is in Wayne County, Kentucky, about 18 miles away. The extension to reach the Oneida region would pass by the group of wells now being drilled in Kentucky near the old Beatty well.

QUALITY OF OIL.

Oil from the Toomey No. 1 well has been analyzed by Dr. Paul C. Bowers in the laboratory of the State Geological Survey with the following results:

Analysis of oil from Toomey No. 1 well.

Base, paraffin.
Color, dark brown.
Gravity, 0.854 or 33.9 Baumé at 15° C or 59° F.
Begins to boil at 58° C or 136.4° F.
Flash point, —6° C or 21° F.
Burning point, 22° C or 71.6° F.
Sulphur.....0.16.
Water.....None.

Fractional distillation.

Light naphtha or benzine, distilling under 150° C	17.29%
Burning oil, distilling under 150-300° C	31.14%
Lubricating oils and residuum, distilling above 300° C	51.57%

A sample was sent to the U. S. Bureau of Mines at Pittsburg. Their analysis is as follows:

Sample of oil from Toomey No. 1 well, 4 miles in northwest direction from Oneida, Scott County, Tennessee.

Specific gravity at 15° C	.8600
Specific gravity (° Be)	32.79
Viscosity (° Engler at 20° C)	2.1
Calories per gram	10689
B. t. u. per pound	19240
Water (per cent.)	Trace
Sulphur (per cent.)	0.18
Sand, etc.	None
Flash point (Pensky-Martens closed tester), below	—5° C.

Digitized by Google

Distillation.

Air distillation made with 5-inch column aluminum beads in modified Hempel flask.

Vacuum distillation in modified Hempel flask without beads.

Air distillation.

Temperature ° C.	Percentage by weight	Specific gravity at 15° C.	Pressure Mm. Hg.
Up to 100	6.9	.689	740
100-125	4.9	.747	740
125-150	4.6	.764	740
150-175	4.7	.778	740
175-200	4.0	.797	740
200-225	4.3	.809	740
225-250	4.4	.824	740
250-275	4.6	.833	740
275-300	6.3	.845	740

Vacuum distillation.

Up to 200	1.7		23
200-225	4.5		23
225-250	7.3		23
250-275	1.3		23
275-300	5.0		23

Total distillates 64.6%

Residue 30.4%

Vacuum fractions contain paraffin wax solid at O° C.

Remarks: Sample can when received was not soldered and was leaking badly.

CONDITIONS OF ACCUMULATION.

From what has been said in discussing the geological structure of the region it may be seen that the conditions under which the oil has accumulated are not yet fully known. From our general knowledge of the structure, it is believed that the oil has not accumulated in a synclinal trough, as it often does where water does not saturate the rocks.

There is no evidence of a pronounced anticline or dome, though it is possible that a reversal of dip may occur west of the West No. 1 well. The writer is inclined to believe that the oil accumulation is due to a local flattening of the rocks, with some reversal of dips from the Toomey No. 2 for some distance to the east, forming a terrace or low anticlinal roll that interrupts the steady general westward rise of the rocks that is the dominant structural feature of the region.

An alternative hypothesis is that the rocks to the east may be or may have recently been saturated with water and that the oil has taken its present position in the rocks as a result of the pressure or buoyant effect and movement induced by the water. If so the oil should occur in a horizontal belt that will lie across the rising rocks like a contour line.

Digitized by Google

Or again, the oil may simply fill porous or fractured and fissured spaces in the Newman limestone without strict regard to either general structural or underground water-level conditions, but its occurrence may be dependent primarily on the presence or absence of such spaces in the rocks.

By keeping careful records of future wells much needed light can undoubtedly be thrown on the underground structure and on the conditions under which oil has accumulated in the region and as a consequence much more intelligent prospecting will become possible and the chances of successful drilling corresponding increased.

TECHNOLOGY.

Drilling.—Derricks and rigs of standard type have been used in drilling some of the wells, while drilling machines have been used in others.

Cost.—It is understood that wells away from the railroad have been contracted for at about $1.65 per foot, while those on the railroad have been taken for $1.50, the driller to move and place his rig and build his derrick, which may afterward be removed by him, or provide his drilling machine, water, fuel and everything except casing.

Water may usually be had in the many small streams of the region except in late summer and autumn when most of them go dry. It may be reached by wells at slight depths anywhere. Coal is available in some places for drilling, and wood may be had in abundance everywhere.

The roads of the region are neither very good nor very bad. They probably average better than in most Appalachian oil regions. Labor may be had at reasonable prices.

LAND HOLDINGS.

Much of the area has been bought in years past for coal and timber and is held in tracts of from 5,000 or 10,000 to 40,000 or 50,000 acres. The owners of a number of these tracts are pursuing a liberal policy in granting leases to parties who desire to develop their leases, but do not encourage leasing to be held for speculative purposes.

WARNING AGAINST IMPOSTORS.

Parties have been operating in the region who profess to be able to locate oil with a device that is supposed to "work" on some heretofore unheard-of electrical principle, when carried by the manipulator over an area where there is oil. It can not be too strongly emphasized that there is no known instrument or device that when carried over the surface may be made to "work" or vibrate or be affected in any manner whatsoever by oil deposits in the rocks beneath. All such claims are fraudulent, and money spent in hiring such "oil finders" is simply wasted, whether they operate with a witch hazel wand, a peach tree switch or a supposed electrical or other device.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Digitized by Google

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 2 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

Digitized by Google

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

Digitized by Google

Vol. III. No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

Vol. III. No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

Vol. III. No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

Digitized by Google

Vol. V. No. 1—The Hydro-Electric System of Tennessee, by J. A. Switzer.
West Tennessee Gullied Lands and Their Reclamation, by R. S. Maddox.
The White Phosphates of Tennessee, by J. S. Hook.

No. 2—Physiographic Influences in the Development of Tennessee, by L. C. Glenn.
Care and Protection of Forests, by R. S. Maddox.
Two Natural Bridges of the Cumberland Mountains, by Wilbur A. Nelson.

No. 3—The Iron Ore Deposits of Lewis County, Tennessee, by Reese F. Rogers.

The supply of Vol. 1 No. 2, Vol. III No. 1, and Vol. V No. 1, is exhausted.

Digitized by Google

ACCESSIONS ROOM
RECEIVED
JAN10 1916
UNIV. OF MICH.
LIBRARY
TN
24
.T2
A4

VOLUME VI NUMBER 1

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY AND OCTOBER
BY THE
STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

JANUARY, 1916

CONTENTS

Oil and Gas Conditions in the Central Basin of Tennessee.....A. H. Purdue
Oil and Gas Conditions in the Reelfoot Lake District of Tennessee.....A. H. Purdue
An Interesting Case of Spontaneous Combustion.....Paul C. Bowers
Sketch of the Work Done by the State Geological Survey in 1915.
Publications of the State Geological Survey.

Entered as second-class matter January 10, 1913, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

VOLUME VI NUMBER 1

TN
24
.T2
A4

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey
NASHVILLE, TENNESSEE

JANUARY, 1916

State Geological Commission

Gov. TOM C. RYE, *Chairman*

Dr. BROWN AYRES, *Secretary*
President, University of Tennessee

H. KNOX BRYSON
Commissioner of Agriculture

Dr. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

R. A. SHIFLETT
Chief Mine Inspector

Geological Corps

A. H. PURDUE
State Geologist

OLAF P. JENKINS
Assistant Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

CONTENTS

Oil and Gas Conditions in the Central Basin of Tennessee.....A. H. Purdue
Oil and Gas Conditions in the Reelfoot Lake District of Tennessee .....A. H. Purdue
An Interesting Case of Spontaneous Combustion.....Paul C. Bowers
Sketch of the Work Done by the State Geological Survey in 1915.
Publications of the State Geological Survey.

Digitized by Google

A typical view of the Embayment area, West Tennessee.

Digitized by Google

Oil and Gas Conditions in the Central Basin of Tennessee*

By A. H. Purdue.

INTRODUCTION.

The public generally is interested in oil and gas, and almost every landowner quietly fosters the hope that one or both of these products may some time be found in the rocks covered by his holdings. Either, found in abundance, is a source of quick wealth, especially if it occurs within easy reach of the market. For this reason, anything that suggests oil or gas is likely to arouse more or less interest in the locality where it occurs, and may lead to unwise and expensive drilling.† Nor is it always necessary to have the "indications", as a reason for the foolish expenditure of large sums, for often wells are put down many hundred feet deep without any good reason for expecting that they will be anything more than dry holes.

To the last statement, many well drillers will reply that some of the richest oil and gas fields of the country have been discovered by men of their vocation, without the aid or advice of a geologist. This claim will be conceded by all who know anything of the history of oil and gas development. It will also be conceded that there are fields, some of them developed and some undeveloped, where the geologist could have been or can be of little or no assistance, especially in the early developments therein. The conditions are of such nature that the geologist is not able to form a reliable opinion as to whether the products occur within the area or not; or if he thinks they do occur within the area, he may not be able to point out the localities

*To make this article as trustworthy as possible, the author submitted the manuscript to Dr. L. C. Glenn, Professor of Geology, in Vanderbilt University, who made valuable suggestions that were embodied in the paper.

†In wet places where the soil or rock contains a good deal of iron, a film of iron hydroxide is likely to form on the surface of small pools, and is often mistaken for oil. If such a film be pricked with a knife blade, it will break apart. A film of oil will not do this.

Digitized by Google

where it is worth while to drill, nor those where it would be useless to expend money.

On the other hand, the geology of most parts of our country is so well known that the geologist, even in territory that has never been drilled, is able to tell where there is no chance for oil and gas, where there is a good chance for one or both, and where the chances though not first class, would justify drilling; and no one should undertake the expenditure of the large amount of money necessary to drill a prospective well, without the advice of a competent geologist. Only be sure that he *is* competent. Such a man will give good advice in regions where the surface criteria and his knowledge of the rocks beneath are such as to enable him to form an opinion. Where there are no surface criteria and he has no knowledge or but limited knowledge of the rocks beneath, he will frankly say so. It is then, and only then, that prospectors are justified in taking their own chances.

In connection with what was said about the lucky strikes of oil and gas without geological advice, it should be said that while the public hears a great deal of such, the knowledge of the dry holes so put down, neither travels far nor lasts long; and their number is many times greater than the successful wells. It is only fair here to state that not all wells located by geologists are successful, by any means. All that a competent geologist would claim would be the ability to designate the areas where there is little or no chance for the products, from those others where there is a possibility of finding them. In this way, he does his clients great service by saving them money that would be spent in hopeless territory, and in reducing their chances for loss by locating wells in the parts of the areas that give promise of responding to the drill.

CONDITIONS FOR OIL AND GAS.

In discussing the oil and gas conditions of the Central Basin, it might be more satisfactory to the reader, briefly to have given the general conditions under which oil and gas occur. These are well known among geologists, and may be stated as follows:

1. There must be a source for the oil and gas.
2. There must be a reservoir to contain them.

Digitized by Google

The source of oil and gas.—Concerning the origin of oil and gas, there are those who think they are formed by chemical reactions that take place within the earth, between different minerals; and those who think they are formed by reactions that take place as the result of organic matter in the rocks. Most geologists, perhaps all, use the latter as a working basis. That is to say, one of the first things they consider when a prospective new field is brought to their attention is whether or not any of the rocks beneath the surface ever contained a good supply of organic matter. If so, this fact, in so far as it goes, is encouraging. The organic matter was put down with the rock beds in which it occurs.

There are those who believe that oil and gas were formed from the remains of animals that lived in the sea at the time the beds were put down; and others who think that they were formed from the remains of plants that grew in the water where the beds were formed, and still others who think the plants were washed in by streams. Plant remains in beds now being formed beneath water have both sources, and doubtless have had ever since there were plants on the earth. The reasonable supposition is that both have contributed to the formation of oil and gas. Likewise, any given reservoir of oil and gas might have had an animal origin or a plant origin, or it might have come partly from the one source and partly from the other.

The reservoir.—It is plain that oil and gas can not accumulate, either in large or small amounts unless the rocks are capable of receiving and holding them. To receive them, there must be cavities of some kind. These may be open spaces in coarse-grained rocks, or joints in fine-grained ones. The coarse-grained, porous rocks are usually sandstones or conglomerates, the former being composed of coarse grains of sand, and the latter at least largely, of gravel, cemented together. Rocks of this kind form the best reservoirs. As gas will move more freely than oil, a reservoir for gas may be in finer-grained rock than for oil. In the same way, a reservoir for very thin oil may be in finer-grained rocks than for thick oil. Sandstones and conglomerates are the common porous rocks, and so frequently are they the rocks from which oil and gas are

Digitized by Google

delivered to the surface, that drillers in quest of these products are on the constant lookout for "oil sands"; but they call any rock that yields oil a "sand".

The fine-grained, or rather the close textured rocks that contain oil and gas, are limestones and shales. Water, like oil and gas, will flow through the coarse-grained sandstones and conglomerates, and many of these are the source of water supply. But if water in quantity is found in close textured limestone or in shale, it must come from joints. The same is true of oil and gas. Such rocks are not considered so desirable as sandstones, for reservoirs.

Oil and gas nearly always occur in stratified rocks, by which is meant those that are in layers or beds. Igneous rocks are not in well defined layers and but few are known to contain oil and gas. The best conditions in rocks saturated with water, occur where the rock beds are bowed upward, forming anticlines. Where the rocks are dry, the oil tends to move down any possible slope and accumulate in the troughs or synclines. Hence in regions of saturated rocks, the anticlines are sought by experienced oil men, while in regions of dry rocks, synclines are sought. Since it is more common to find the rocks saturated than dry, attention is mainly directed to the anticlines.

Another essential for a reservoir is that the open rock be covered with a "tight" or close textured one, so as to seal the oil and gas in. Without such a covering, these elusive products will escape upward and be scattered through the overlying rocks in inappreciable amounts, or what is more probable in the case of gas, will be given off into the air above.

It seems not improbable that nearly all stratified rocks originally contained organic matter that has produced more or less gas or oil, but if so, most of these have given up their products by dispersion to other rocks and to the atmosphere, from want of adequate sealing-in conditions. In the case of oil under such conditions, much of the gaseous matter has escaped from it, leaving asphalt and its kindred products, such as albertite, ozokerite, grahamite, and gilsonite.

Yet another condition usually given as an essential for a reservoir, is that the open rock be underlain by a tight layer,

Digitized by Google

like the overlying one, for the reason that oil or gas may be dissipated downward as well as upward.

Size of the reservoir.—The size of the reservoirs in which oil and gas are stored may not be larger than a pea, or it may cover many square miles. Examples of the small ones may be found in many limestones, in which occur cavities filled or partly filled with petroleum. Such limestones are seductive, for they excite prospecting, but seldom yield oil in paying quantity. The cavities may be numerous and all may contain some oil, but they are not connected, and consequently there is no possibility of the oil flowing from one to another and finally into the drill hole, from which it can be pumped to the surface.

Most of the large reservoirs are in sandstone, the storage space being composed of the infinite number of pores between the sand grains composing the rock. In fact each one of these small pores is a reservoir in itself, but they are all connected, and because of this the oil or gas will flow through the rock a limited distance to a drill hole. The actual distance through which it will flow varies, being short for small pores and low rock pressure, and comparatively great for large pores and high pressure.

Shape of the reservoir.—Where folding is a factor in forming the reservoir, its shape depends upon that of the structural features. If in an anticline, and the anticline be dome shaped the outline of the reservoir will be circular; but if the anticline should be of the common, elongated kind, the reservoir will be more or less linear in outline. For this reason, geologists and experienced well drillers work out the structure and follow it, not only in trying out an undeveloped field, but if the rocks prove to be saturated with water, in extending it after a successful well has been drilled.

But here the layman must be warned against making the common mistake of supposing that the bending of the rock layers conforms to the surface irregularities. The rock layers cannot be supposed to bow upward where there are hills and downward where there are valleys. If they are not level, they perhaps more commonly bow downward in the hills as synclines and upward beneath the valleys as anticlines; or more commonly yet, they dip in one direction as monoclines. In the

Digitized by Google

latter case, the hard rock layers occur in the ridges, and the soft ones in the valleys.

Angle of the rock beds.—Folded rock beds may stand at any angle from near the horizontal to the perpendicular. The most desirable position for oil or gas is the one near the horizontal. This, for the reason that the lower the dip the wider the anticline and consequently the larger the field; and for the further reason that it is easier for the driller to put down a straight hole in rocks of low than of high dip. If the rocks dip as much as 20 degrees, it is difficult to drill a straight hole, especially if they consist of alternating beds of shale and sandstone or other hard rock. When the drill passes through a soft bed and strikes a high-dipping hard one, the tendency is for the bit to slip downward over the hard surface, and turn the hole away from the perpendicular. Yet, with care, an experienced driller can put down a straight hole in alternating beds of sandstone and shale that dip 20 degrees, or even more.

Horizontal reservoirs.—There are reservoirs that consist of lenses of sandstone lying horizontal or nearly so, sealed up in beds of shale. In such cases, neither the geologist nor the driller can locate the reservoir, without drilling. It follows that the striking of such reservoirs with the drill is a matter of chance; and after such a reservoir is struck, its size can be determined only by the driller.

THE CENTRAL BASIN.

It is for the double purpose of preventing further loss from what geologists believe is a hopeless quest for oil and gas in the Central Basin, by those who might in the future make the venture, as others have done in the past, and put down wells without geological advice; and for answering the question that frequently comes from those who are more cautious, as to whether oil and gas occur within the Central Basin, that this paper is written.

Enticements to prospecting—In the past, more or less interest has been aroused in many parts of the Central Basin over oil and natural gas. In places this has resulted in the expenditure of money by drilling wells from a few score to a few hundred

Digitized by Google

feet deep, and in some cases several hundred feet deep. The stimulus to the sinking of the shallow wells has been the finding of small pockets of oil or gas, usually in drilling for water. When such are struck, the common belief is that by going deeper, a good supply would be found, but this has always resulted in disappointment. The conditions over the Central Basin are unfortunate for the reason that oil and gas are sufficiently common to entice people into spending money in their quest, yet they probably nowhere exist in paying quantities.

The reasoning followed by those who have backed the more pretentious searches by deep drilling, probably has been somewhat as follows: The striking of oil or gas is only a matter of luck anyway, and there is as good show for these here as anywhere. So we will take the chance. Or it may have been this way: Oil occurs in West Virginia and Pennsylvania. It also occurs in Louisiana, and we are on the line between the two. Therefore, oil should be found here. Without going into details, the writer wishes to say that neither of these supposed reasons are reasons at all, and no one should ever permit himself to be pursuaded to part with his money upon any drilling venture that has no more claim for merit than they contain.

Nature of the rocks.—The rocks that form the floor of the Central Basin are nearly all limestone. These rocks extend up a short distance above the floor around the edge of the Highland Rim and pass off in all directions beneath it. They are of Ordovician age, though this is of little interest to the prospector, except that a good portion of them belong to the Trenton division of the Ordovician. Many drillers still look with favor on rocks of Trenton age because these are the rocks that supplied the eastern Indiana and western Ohio field, which was in prominence 20 years ago. But it is one of the mistakes of drillers to suppose that Trenton rocks everywhere contain or are liable to contain, oil and gas.

The formations composing the above mentioned limestones, named from the upper to the lower ones are Leipers, Catheys, Bigby, Hermitage, Carters, Lebanon, Ridley, Pierce and Murfreesboro. The maximum total thickness of these formations exceeds 800 feet. Below the Murfreesboro limestone, but not

Digitized by Google

exposed anywhere within the Central Basin, is a formation called the Knox dolomite. This formation extends eastward beneath the Cumberland Plateau and is the surface rock in a large part of the Valley of East Tennessee, having received its name from Knox County. It is composed of limestone, dolomite, and a small amount of sandstone, and in East Tennessee reaches a thickness of 3500 feet. Its thickness in the Central Basin is not known, but that it occurs there is shown from its appearance in Wells Creek Basin 40 miles northwest of the Central Basin, in the southwestern part of Stewart County. It is not probable that the thickness of this formation in Middle Tennessee is as great as in East Tennessee.

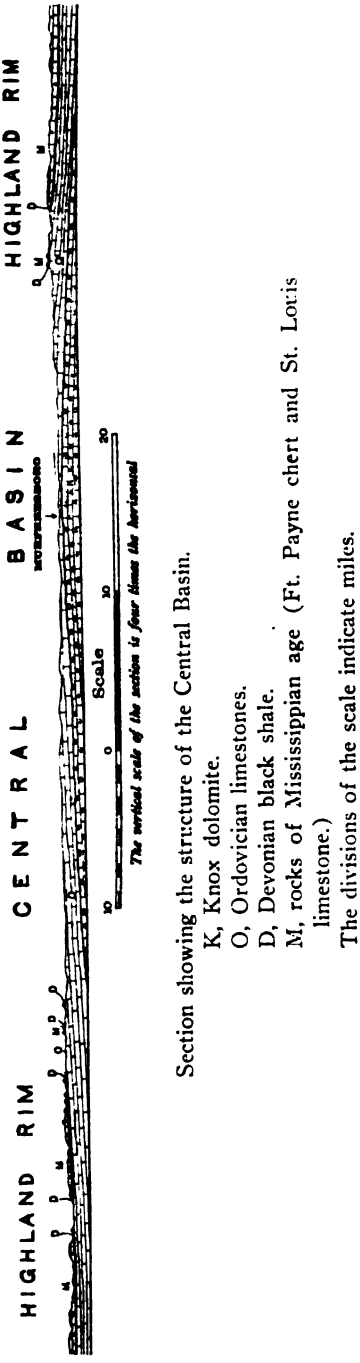
With the exception of the Pierce formation, practically all the rocks of the Central Basin are limestone, and even this formation is itself composed of limestone and limey shale.

Structure of the Central Basin.—If the rocks of the Central Basin were level, only the upper formations of those named above would show at the surface; but instead, the Basin is a great arch, or rather a dome, of slight elevation. In general, the arching does not end where the rocks pass under the Highland Rim, but continues a greater or less distance beyond. The figure herewith will give a general idea of the structure.

The highest part of the dome occurs in the vicinity of Murfreesboro, Rutherford County; and here, all the upper formations have been removed down to the Ridley limestone, the Pierce shale, and the Murfreesboro limestone. This removal of the rocks is a part of the general one that has taken place all over the Central Basin, and to this the basin owes its existence. The process of removal has been mainly by solution. The Highland Rim has escaped removal, because the rocks composing it are more siliceous than those of the Central Basin and for this reason have resisted the solution that took place in the comparatively easily soluble limestones of the latter area. The agent of solution was the water that fell as rain, and flowed off over the surface and through the rocks.

As the rock beds were arched up higher in the vicinity of Murfreesboro than elsewhere, it will be seen that the removal of the rocks from the area would bring the lower and older

Digitized by Google



Section showing the structure of the Central Basin.
K, Knox dolomite.
O, Ordovician limestones.
D, Devonian black shale.
M, rocks of Mississippian age (Ft. Payne chert and St. Louis limestone.)
The divisions of the scale indicate miles.

ones to the surface in that locality. The Ridley limestone and the Murfreesboro limestone are separated only by the Pierce shale, which is a thin formation, less than 30 feet thick, and like the other two, is in most places covered with soil. Where this is exposed it can easily be recognized, but the Ridley limestone and Murfreesboro limestone are so much alike that it is difficult for even the geologist to distinguish them except in places where they can both be seen, with the Pierce shale between them. In such places, it is known that the limestone above the shale is Ridley, and that below is Murfreesboro.

It must not be supposed that the rock beds dip off uniformly from the highest part of the arch, like the surface of a very flat dome. Rather, they are in small, wave-like folds, the beds here passing downward, forming troughs, and there upward, forming arches. From the somewhat limited investigation made by this survey, it appears that none of these folds are long, but die out in short distances and are succeeded by others, giving the whole structure a wobbly form.

Digitized by Google

Natural gas and oil conditions as applied to the Central Basin.—As above stated, the rocks of the Central Basin are nearly all limestone. Limestone is formed by the chemical precipitation of lime carbonate from sea water, and by the shells of animals that die in the sea. The large number of fossil shells found in the limestones of the Central Basin prove that they were formed at least in large part from animal remains. The probability is that the amount of such remains was sufficient to form a good supply of oil and gas. So we can reasonably conclude that the first condition for forming these products in commercial amount was supplied in the organic remains put down with the rock.

But when it comes to the other condition, that is the reservoir for containing the oil and gas, the prospect is not so favorable. It is true that the area itself is occupied by a great, flat arch, upon the sides of which are numerous small, wave-like folds. So far as this goes, the conditions are most favorable indeed. But the rocks, like most limestones, are close textured. There are no pores in which oil and gas may collect. The only receptacles for such are in the joints that penetrate the limestone beds. These, in places at least, are probably numerous enough to form gas reservoirs of considerable importance, but there is no fine-grained stratum to seal this in, and most of it has escaped into the air. The nearest approach to a cover that would retain the gas is in the Pierce shale, but this is a thin formation, and is itself too limey and too much jointed for an effective cover.

As above stated, there are numerous localities over the Central Basin where a small amount of gas and some oil have been sealed in, and these are not infrequently struck in drilling for water. But the oil is insignificant in amount where it occurs at all, and the gas usually exhausts after a few days' flow. The greatest supply of gas they could be expected to furnish would be for private use, such as heating a residence, or a kitchen range. In most cases, the supply would be too small to justify the necessary piping even for one of these purposes.

The question often comes up as to whether it would be advisable to go deeper in those wells of the Central Basin that produce gas. To this question, no general answer can be given.

Digitized by Google

Whether or not deeper drilling would be advised in order to get a supply of gas for household use would depend in each case upon the location of the well. In some wells, doubtless deeper drilling would result in an increased flow of gas, but in no case would it be thought advisable to drill very deep. It is the belief of the writer that such limited reservoirs of oil and gas as occur in the Central Basin will be found in those rocks that lie above the Knox dolomite. Possibly an appreciable amount of these products would be found in the upper part of that formation, but every foot of descent through it, decreases the prospect of finding any.

In the vicinity of Murfreesboro, where the arch stands highest, the Knox dolomite would be reached near the surface, and would be deeper the greater the distance from that area. This will be made plain by inspecting the figure on page 11. Its greatest depth would be found next to the Highland Rim. Where all the formations of the Basin occur above the Knox dolomite, its depth from the surface would be the aggregate thickness of those formations, which is approximately 800 feet.

Conclusion.—As the reader has gathered from the foregoing, it is the writer's belief that oil will nowhere be found in utilizable amount in the Central Basin, and that gas can not be expected in greater amount than a supply for private use. The most likely localities for such supply are in the outer parts of the area, and in the tops of the folds or wobbles that occur on the sides of the main arch.

OIL AND GAS WELLS.

It should be remembered that this paper is confined to the oil and gas conditions of the Central Basin. It does not include the surrounding Highland Rim, in which the oil and gas conditions are more or less different.

Besides the numerous shallow wells of the Central Basin that have produced a showing of oil and more or less gas, Mr. M. J. Munn has reported several deep ones.* In order to get the known facts of the area together, what Mr. Munn has to

*Preliminary report upon the oil and gas developments in Tennessee. Bull. 2-E, Tennessee Geological Survey, pp. 29-31.

Digitized by Google

say about these wells is here reproduced. It will be seen that the results support the general belief among geologists who are familiar with the Central Basin that oil and gas do not occur there in commercial amounts. What Mr. Munn says about these wells is as follows:

Lincoln County.—While Lincoln County is embraced by the Highlands, much of its surface consists of large valleys and lowlands where the outcropping rocks are of the same age as those of the Central Basin.

Five wells have been put down in this county in search of oil and gas or for large supplies of water. One of these was located near an old oil spring south of Argyle in the southwestern part of the county. Another well was drilled still farther to the southwest near Blanche. Both of these wells are reported to have found a small amount of oil, but details regarding them could not be secured. In the northwestern part of the county near Petersburg a well was started in search of oil on the Brown property in 1900 or 1901, but, after getting a "show" of oil, a string of tools was lost in the well at a depth of about 1,000 feet, and the hole abandoned. A considerable flow of gas with salt water was found at about 800 feet in a well drilled at Fayetteville to supply water for the city. This gas was not utilized, though it is said to have occurred in sufficient quantities to have been of commercial value if the well had been properly handled. A well drilled for water on the farm of Mr. Richard Smith at Smithland found sufficient gas at a shallow depth to be utilized by him for household purposes. Aside from the above wells a large number of shallow ones, drilled for water over the county, have shown more or less oil, gas and some salt water, but to date wells are too few to furnish reliable data regarding the possibility of oil and gas pools of commercial size being found in this region.

Giles County.—A deep well drilled in search of water in Pulaski is said to have reached a depth of 2,200 feet, in which small "shows" of both oil and gas were found. No other deep wells are known to have been drilled in this county, though numerous surface indications of both oil and gas occur.

Marshall County.—All but the southern portion of Marshall County lies within the Central Basin. In this county a few miles northwest of Lewisburg a well was drilled on the G. O. McRody farm for oil, about the year 1900. This is said to have reached a depth of 982 feet and to have furnished some gas. Near Ostella, in the southern part of the county, a water well drilled about 25 years ago on the John Bradford farm furnished considerable gas. South of Lewisburg in the vicinity of Yell and Cornersville many wells drilled for fresh water have supplied small quantities of oil, gas, salt water and sulphur water. One of these wells on the F. M. Parks farm is said to have furnished sufficient gas at a depth of 170 to 190 feet to burn in a flame from 10 to 20 feet high from the mouth of the well.

Maury County.—No deep wells have been drilled for oil and gas in this county. A shallow well sunk for water near Lovettsville in the eastern part

Digitized by Google

of the county on the W. A. Jackson farm found gas at 90 feet in such quantities as to burn for several years from 20 to 25 feet above the well mouth. Other shallow wells at several places in this county have furnished small quantities of oil, gas and salt water. There are also many oil and gas springs, one of which is located under the river bluff at Columbia, where a constant, though small, supply of oil seeps from the Lebanon limestone.

Bedford County.—The first well drilled for the purpose of testing for oil and gas in this county was put down in 1886 or 1887 at Shelbyville, the county seat. It was drilled by a local company on a lot owned by Mr. B. R. Whitthorne and reached a total depth of 1,000 feet. The hole was 8 inches in diameter down to 363 feet, the remainder being 5 inches. Fresh water was encountered at several places in the 8-inch hole and brackish and mineral water at greater depths. Few indications of oil and gas were encountered, and the hole was plugged at 363 feet. In 1908 this well was cleaned out, pumping machinery installed, and the water from the 8-inch hole has since been utilized by the railroad company and for ice making. In 1902 or 1903 a well was drilled on the Swiver property, about 2 miles north of Wartrace, on the dirt road to Bellbuckle. This well is reported to have been drilled to a depth of 1,800 to 2,000 feet, but no data relative to it could be obtained. In 1904 or 1905 a well was also drilled for oil on the Matthew Skeen farm, about 1 mile north of Bellbuckle. This well is said to have been put down to a depth of 1,500 feet, but nothing is known of the results obtained. In 1906 or 1907 a well was drilled on the Zach Crouch farm, about 3 miles east of Bellbuckle, by the Wimber Oil Development Company. This well is said to have furnished no oil or gas. Many surface indications of oil and gas occur throughout this county. These consist of small seepages of oil from the limestone at many places and of local deposits of gas or small quantity encountered in shallow wells drilled for water. Several such indications have been found near Shelbyville and a noted oil seepage exists in the bluff of Duck River, south of this town. These indications led to the drilling of the deep well at Shelbyville. Considerable land is now under lease in this county for oil and gas.

Rutherford County.—As many as five wells have been drilled in this county in search of oil and gas but without finding either in commercial quantities. Several shallow wells drilled for water in the vicinity of Murfreesboro at various times since the Civil War furnished good indications of gas. One of these wells, on the Overall property, about 1 mile west of town, contained sufficient gas to cause the owner to attempt to utilize it for heating and lighting his residence. The gas, however, was repeatedly shut off by invasions of fresh water, and the attempt was for this reason, a failure. These indications led to the drilling of three wells near Murfreesboro. The first of these was on the House property, about 3 miles northwest of the town; the second on the E. W. Talley farm, about 7 miles from Murfreesboro and about 2 or 3 miles southward from Florence; the third well about 3 miles southwest of Murfreesboro on the W. B. Cooper farm. This well is said to have reached a depth of more than 1,000 feet, much trouble being experienced in getting

Digitized by Google

the hole down. It is said to have flowed water from near the bottom. None of the wells is said to have furnished more than good shows of oil and gas. Two deep wells have also been drilled in the extreme southern part of the county near Fosterville on the J. G. Miller and B. F. Ransom farms. In the last named well the indications for oil are said to have been very favorable, but no information regarding depth to, and amount of, oil obtained is available. Several areas of considerable extent in this county are now under lease, but no drilling operations are being conducted at present.

Wilson County.—Although several large blocks of leases have been taken by oil and gas companies in this county since 1896, the drilling has been confined to a single well put down by the Union Oil & Development Company of Baltimore, Maryland, on the Chambers property near Moxie, about 5 miles north of Lebanon. This well is said to have reached a depth of about 1,000 feet without finding oil or gas.

Cannon County.—In this county near Woodbury a well was drilled several years ago by the South Penn Oil Company on the McFerrin property. It reached a depth of about 1,700 feet without finding oil or gas. Large quantities of Blue Lick water are said to have been found between 1,000 and 1,700 feet from the surface. Another well on the Samuel Banks farm was drilled to a depth of 600 to 800 feet in search of water. It is said to have furnished gas of sufficient pressure to blow the heavy drilling tools from the well. No other deep holes are known to have been drilled in this county.

Smith County.—This county lies in the northeastern part of the Central Basin, and so far as known but two wells have been drilled for oil within its borders. The first well was drilled shortly after the Civil War on the McMurray property, in the extreme northwestern portion of the county near Dixon Springs. This well is said to have reached a depth of several hundred feet and to have furnished "shows" of oil. In 1896 a well was drilled by the South Penn Oil Company on the T. J. Fisher farm, a short distance northwest of Carthage, the county seat. This well reached a depth of 900 feet, finding water at 235, 255 and 400 feet from the surface. An imperfect record of this well gives a thickness of 888 feet of limestone, no mention being made of shows of oil or gas. Numerous oil and gas springs occur in this region, especially in the vicinity of New Middleton, in the southwestern portion of the county, where it is said that many shallow wells drilled for water contain small quantities of oil and gas and much salt water.

Davidson County.—The writer was unable to secure any definite information relative to deep wells drilled in this county, though it is very probable that several tests have been put down for oil and gas. Shows of oil and gas in wells drilled for water have been found at many places in the limestones of the Central Basin and a number occur in Davidson County, but no pools of commercial size have yet been found.

Digitized by Google

Oil and Gas Conditions in the Reelfoot Lake District of Tennessee*

By A. H. Purdue.

INTRODUCTION.

Within the past year, a good many inquiries have come to this Survey about oil and gas conditions in the Reelfoot Lake area, and in quest of oil one well has been put down near the east shore of the lake, a short distance south of Samburg. At least one other company has been formed for the purpose of drilling, but at this writing they have not begun operations. The general search for oil and gas will continue for many years to come, and further inquiries are sure to be made about the possibility of finding these products within the area under consideration. This fact supplies the reason for this paper. Also, the question sometimes comes as to the general oil and gas conditions in West Tennessee, and in search of these products some wells were in recent years put down near Memphis. These have been reported on by Ashley and Munn.† This paper supplements the information given by those authors, for the reason that oil and gas conditions in the Reelfoot district can not be intelligently discussed without more or less attention to those of the Embayment area in general.

REASONS WHY THE REELFOOT LAKE AREA HAS ATTRACTED PROSPECTORS.

In stating the reasons why the Reelfoot area has attracted the attention of prospectors, it must not be understood that the writer is giving them his indorsement. It appears that three things have brought the attention of oil and gas men to

*For a good understanding of this article, the layman should read that part of the preceding one that relates to the conditions for the occurrence of oil and gas.

†Ashley, Geo. H., Tenn. Geol. Survey, Bull. 2-E, pp. 40-46; and Munn, M. J., *Res. of Tenn.*, Vol. II, No. 2, pp. 42-68.

Digitized by Google

this area. Probably the most important consideration that aroused an active interest in the area is that it is in the center of the well known series of earthquakes that occurred in 1811-12.

Another thing that directed attention to this area as a possible oil and gas producer, is its surface resemblance to the Louisiana oil and gas field; but as similar surface conditions obtain along the Mississippi River from Cairo to the gulf, this fact probably was not so influential as the one already given.

FIG 1. Rotary drill, operating at Reelfoot Lake. (A. H. P.)

A third thing that excited prospecting is the alleged existence of springs around the borders of the lake, that are said to produce some oil and gas.

THE REASONS CONSIDERED.

The reason of an earthquake center.—The reason why those interested in prospecting the area connect the possible occurrence of oil and gas with the earthquake of 1811-12, and subsequent ones of minor importance, does not seem to be well defined. Whether or not the probable occurrence of oil and gas here can be deduced from the changes that took place during those disturbances might be, at least in part answered, by noting just what ones did take place.

Digitized by Google

It is established by the writings of numerous men of high standing, as well as handed down by tradition, that during this series of earthquakes, numerous changes took place in this area and in near-by portions of Arkansas and Missouri. These changes consisted mainly in the subsidence of certain parts, converting them from a condition of more or less dry land to lakes.

The area of Reelfoot Lake, approximately 25 miles long, with a probable average of five miles in width, was previous to the earthquake, one of low land probably containing a good many

FIG. 2. Dead cypress trees in Reelfoot Lake. (A. H. P.)

old sloughs, and certainly one or more streams. Without the witnesses of tradition and literature, that of dead trees yet standing in the lake is convincing proof that the area recently has been submerged. The submergence could have come about either by sinking or by an elevation of the land immediately to the south, thus ponding the water; but if there was any such elevation it was not great enough to have formed the lake; besides the stream flowing out of the lake to the south would probably by this time have cut its bed down through the soft material over which it flows, and thus drained most of the area. So we must conclude that sinking took place.

Digitized by Google

Along the eastern border of the lake, there is a bluff more than 100 feet high, composed of soft beds of Tertiary age at the bottom, and a deposit of fine sand and clay at the top, known as loess, with a thin layer of gravel between the two. This bluff extends northward to Hickman, Kentucky, where it runs into and becomes a part of the bluffs of the Mississippi, and southward below Vicksburg, with the exception of breaks by such streams as Obion River, Forked Deer River, Hatchie River, Wolf River and others entering the Mississippi River from the east. This bluff is in places the present bank of the Mississippi River, as at Memphis, and in others a former bank, as east of Reelfoot Lake. A look at it from Hickman southward to Obion River, is enough to convince any one familiar with the shifting from side to side of the Mississippi River, that it is an old river bluff, and that Reelfoot Lake occupies a former river bed. The bluff is in no way due to the earthquake, as some interested in prospecting the area have supposed. The earthquake affected it, as may yet be seen, by forming fissures and terraces of limited extent on its surface. Such of these as the writer has seen are in the nature of landslides, and do not represent true fissureing.

Conclusive evidence that the site of Reelfoot Lake is a former river course may also be seen by one who has observed land surfaces in areas of shifting streams, in the gradual slope from the rich level, alluvial plain west of the lake, to the water's edge. This is plainly to be seen from a point east of Tiptonville, southward to the end of the lake.

That the site of the lake was an old river course, and was low land before the earthquake, is stressed for the purpose of eliminating the notion held by many that there was excessive sinking in this area, caused by the earthquake. It was an area, like all young river bottoms of flood-plain origin, made up of low ridges with intervening troughs, some of the latter filled with water a part or all the time, the whole having been drained by a stream of considerable size and probably several tributaries. It appears that this stream was called Reelfoot Creek before the earthquake, and it was this that gave the name to the lake.

Digitized by Google

With the picture before us of a wide bottom area, composed of low ridges and sloughs, it will be seen that sinking of only a few feet was necessary to form the lake. The writer has not been over the lake extensively, but he has crossed its widest part along two lines, and his conclusion, judging from the present depth of the water, the dead trees yet standing in the water, and information gathered from those familiar with the lake, is that the sinking nowhere much exceeded 20 feet, and that the average probably was less than half that amount. The statement sometimes heard, that the tops of trees may be seen barely projecting out of the water is not supported by the writer's observations nor the word of reliable men who have for years followed the business of fishing on the lake. The mulberry, one of the less common of the dead trees now standing in the water, is even yet occasionally cut to make posts of the trunk. All familiar with this tree know its trunk is short, and if enough stands above the water for a post, not much can be left beneath the surface. To be sure the mulberry grew on the highest ridges of the bottoms, but these were not far above the sloughs.

A flat-topped, circular Indian mound on the west edge of Chocktaw Island, west of Samburg, is somewhat more than 100 feet in diameter and stands approximately 8 feet above the water. As these mounds are never very high, the sinking could not have been excessive at this point. Off the shore of the island, the dead cypress trees are said by those familiar with the water to stand 16 feet beneath the surface. They also report that this is one of the deepest parts of the lake. Not allowing for filling, this would make the top of the mound 24 feet above the slough in which the cypress trees grew. Other Indian mounds are reported in the lake. That they were built here is in keeping with the custom of the Indians of the Ohio and Mississippi rivers, along which many mounds are found in swampy places.

Incidentally, it might be said that the growth of timber over the sunken part was luxuriant, as is shown by the number and size of the dead cypress trees still standing in the water. These will number from 4 to 10 to the acre, the largest ones being as much as 3 feet in diameter. Much of the smaller cypress tim-

Digitized by Google

ber and nearly all of other kinds have rotted off at the water surface, and fallen.

Tradition has it that the area between Reelfoot Lake and the river was elevated during the earthquake. The investigations of Mr. M. L. Fuller* and others establish the existence of a dome extending from "the vicinity of New Madrid southward to the vicinity of Caruthersville, a distance of 15 miles, and from a point west of the Mississippi to Reelfoot Lake, a distance of 5 to 8 miles." Mr. Fuller states that some of the doming was almost certainly due to the earthquake of 1811, but says that if Little Prairie, on which New Madrid is situated is a part of the dome, the uplift will have to be referred to an earlier date, as New Madrid village previous to the shock was on high land, never covered by the floods.

It is the present writer's belief that if any doming took place in 1811, it was very slight indeed, for the level alluvial plain on which Tiptonville stands is now probably not more than 6 to 8 feet above the level of the lake. It must have had approximately this elevation before the earthquake, for it is said to have been timbered with oak, ash, sycamore, sweet gum, and other trees that thrive in land that is fairly well drained. The timber of the lake area was chiefly cypress, which proves a low, swampy condition before the earthquake.

As further evidence of a comparatively high elevation of the land west of the lake before 1811, it is stated by the present residents that some of the land about the present site of Tiptonville was then cleared and in cultivation.

The probable existence of this dome before the earthquake makes it much more inviting as a possible source of oil and gas than if it had been formed during that time, for the reason that the deep-seated agencies that caused it affected all the deposits of the area, down to the old rock floor. These deposits are described later in the paper. The effects of the earthquake were largely if not wholly superficial. Also, the accumulation of oil and gas is such a slow process that the time since 1811 is too short for any considerable store of either to have been formed.

*U. S. Geol. Surv., Bull. 494, p. 63.

Digitized by Google

What has been said is in the attempt to make it clear that there is little or no connection between the earthquake and its results and the possible occurrence of oil and gas. The sinking was nowhere very great and it is the writer's belief that the material affected did not reach far beneath the surface. It was a superficial phenomenon, due mainly to the soft, mucky nature of the material of the old abandoned river course, but possibly in part to the soft Tertiary deposits immediately beneath, that were saturated with water. That this is true is shown by the sinking having been confined to the old river course. The area was underlain by muck and water-filled sand and the low ridges were in a sense floating islands, on this material. The writer believes that the sinking took place by the settling of the material under the influence of the shake, by the squeezing out of the muck into the sloughs and stream channels and as mud spouts here and there over the surface, and by forcing water from the saturated sand lenses to the surface. Certainly, the sinking was one of the results of the earthquake, and not a cause.*

Even if it be granted that the phenomenon was a deep-seated one, this would be unfavorable to the presence of oil and gas in the immediate vicinity of the lake. For the fissuring of the material down to great depths probably would have left rents from which they, especially the gas, could escape.

Resemblance to the Louisiana field.—There is a general resemblance between the Reelfoot Lake area and the Caddo oil and gas field of Louisiana, in that they are both low and poorly drained, and both contain shallow lakes. But these are superficial matters that have no bearing on the occurrence of oil and gas. The land of the Reelfoot Lake area is low because it, in common with the region from the bluffs on its eastern margin, westward to Crowleys Ridge in Arkansas, is one of river erosion. There is no more reason to expect a successful oil well on the border of the lake than at Dyersburg or Union City or

*This discussion refers only to the Reelfoot Lake district; but from what the writer has seen of the "sunk lands" in northeast Arkansas he thinks the same explanation of origin will in general apply to them. For a full discussion of the New Madrid earthquake, see Shepard, E. M., *Journal of Geology*, Vol. XIII, pp. 45-62. Also Fuller, M. L., U. S. Geol. Surv., Bull. 494.

Digitized by Google

any other point between. For after the drill passed through the material of the bluff, and on down past the level of the old river bed, as far as anybody can now tell, the same strata would be penetrated and the same conditions encountered at any of the latter places as immediately about the lake.

As for the surface resemblance of the two areas, that counts for nothing; but there is a similarity of geological conditions that is worth attention. This is brought out below, in discussing the geology of the Embayment area.

Oil and gas springs.—As above stated, the writer has not seen any of these reported springs, but concerning the occurrence of oil in them, he is exceedingly skeptical. What is thought to be oil, more likely is a film of iron hydroxide, which is not uncommonly seen on the surface of small pools of water in boggy places, and which is frequently mistaken for oil.

These springs probably are not deep-seated. More likely they receive their supply from the water of the land that stands above the lake shore. This is true of the few springs that the writer has seen along the east margin of the lake, the water of which comes from the material of the bluffs. Such springs as issue down near the edge of the lake would be expected to contain more or less marsh gas, derived from the decay of the organic matter buried in the alluvial deposits bordering the water.

GEOLOGY OF THE AREA.

A consideration of the possible occurrence of oil and gas within the area under consideration forces attention to its geology, and this in turn requires that the main facts in the geology of the Gulf states be reviewed.

The lowlands of the Gulf states, including western Tennessee and Kentucky and eastern Arkansas, lie in what is known as the Embayment area. The northern limit of this area reaches a short distance across the Ohio River in the vicinity of its mouth. The rocks of most land areas were put down beneath the sea and those of this one are no exception to the rule, if we do not include those within comparatively few feet of the top,* concerning the origin of which there is some doubt. However,

*The loess and the Lafayette formation.

Digitized by Google

the deposits of the Embayment area differ from those that surround it in being much younger and in consisting for the most part of soft, unconsolidated material, such as sand and clay. The youth of these deposits is due to their having been put down during comparatively recent invasions of the sea, at which times the Gulf lapped over upon the continent, each covering more or less of those parts of Tennessee, Arkansas and the other states above named, as lying within the Embayment area.

There were several of these invasions of the Gulf. The first one covered the eastern part of Texas, reached up into southern Arkansas, and extended eastward well into Alabama, and at least as far as Wayne County in Tennessee. This was during what is commonly called Lower Cretaceous times, and the deposits put down in the seas of this time are accordingly of Lower Cretaceous age.† The northern extent of these deposits is not known, because in that direction they are covered by younger formations. In Arkansas and Texas they consist of beds of chalk, limestone, sand, clay and gravel. Where exposed in Hardin and Wayne counties, Tennessee, they consist of sand and gravel.

After the Lower Cretaceous beds were deposited, the Gulf retreated to the south, leaving the topmost of those beds forming a land area. The extent of the southward retreat of the shore line is not known. After a considerable lapse of time, it again advanced northward, this time reaching past the present site of Cairo, Ill. This was during what is commonly called Upper Cretaceous* time, and the deposits then put down are of Upper Cretaceous age. These deposits are in three formations, known as the Eutaw sand, the Selma clay, and the Ripley formation. They are important in this connection, for if oil or gas or both, occur in the Embayment area, they are more likely to come from some of these formations than from the younger ones above. They will have more attention later in this paper

After the deposition of these formations, the sea again withdrew to the south, leaving the younger of these rocks and possibly some of the edges of the older ones as a land area.

†This is also called the Comanchean period. *Geology*, by Thomas C. Chamberlin and Rollin D. Salisbury. Henry Holt and Company.

*Chamberlin and Salisbury call this the Cretaceous period.

Digitized by Google

After another considerable lapse of time, the sea again encroached upon the Embayment area. On the Arkansas side, it seems to have extended further west than it did during the Upper Cretaceous advance, and it reached equally as far north; but in Tennessee it perhaps did not reach so far east as did the Cretaceous sea. This was during Tertiary times. The invasion was much interrupted, the shore line having shifted back and forth over the area many times.* The deposits then put down are of Tertiary age. As a result of this shifting, the deposits are much complicated, and the several divisions are now known under as many different names, but for the sake of simplicity they will here be described under their old names, the Porters Creek and Lagrange formations. After the deposition of the younger of these formations, the sea again retreated, again leaving the area as dry land.

There are gravels and sands, generally known as the Lafayette formation, over more or less of the area, but the origin of these is in doubt. For this reason, and because this and a yet younger formation that occurs along the Mississippi River, known as loess, do not enter into the problem of oil and gas, they will not be considered further.

Cretaceous formations of Tennessee.—The Cretaceous deposits of the Embayment area are mainly of Upper Cretaceous age. They have been described by the late Dr. James M. Safford in the *Geology of Tennessee*, by Dr. L. C. Glenn**, by Dr. L. W. Stephenson,† and others. ‡

For the purpose of description, the lowest part of the Cretaceous deposits in Tennessee may be called the Eutaw sand, that being the name by which it has been known in recent years.§

*Berry, E. W., U. S. Geol. Surv., Prof. Paper, 95-F.

**U. S. Geol. Surv. Water Supply and Irrigation Paper, No. 164.

†U. S. Geol. Surv., Prof. Paper, No. 81.

‡Mr. Bruce Wade is making a careful study of these deposits for this Survey, but his work is not yet finished, and no part of his results have been published.

§The work lately done by Messrs. H. D. Miser and L. W. Stephenson of the U. S. Geological Survey and Mr. Bruce Wade of this Survey, indicates that the lower part of what is here called Eutaw sand, is Tuscaloosa, a formation well developed in Alabama, but less so in Tennessee. Its most conspicuous development in Tennessee is on the hills east of Tennessee River. It is considered of Lower Cretaceous age.

Digitized by Google

The formation consists largely of loose sand, but it is interbedded with lenses of clay. It was put down in shallow water that contained rather strong shifting currents, that here and there along the course of their greatest strength, scoured out the bottom. The troughs thus formed were soon filled up by other sand and clay, the result being irregular deposition—a prominent character of the formation.

While lenses of clay enter rather largely into the composition of this formation, its character as a whole, where it is exposed, would not interfere with the free circulation of water or of oil, should it contain that product. It contains more or less brown-coal or lignitic material, and petrified wood. The thickness of the Eutaw formation in Tennessee is thought by Dr. L. C. Glenn to be from 250 to 275 feet.*

This formation shows at the surface in Tennessee only in parts of Benton, Decatur, Henderson, Hardin and McNairy counties. That it is continuous entirely across the Embayment area is indicated by its probable occurrence in southeastern Arkansas where it is known at the Bingen sand.† Its northward extent is more doubtful, as it is overlapped in that direction by younger deposits. It may reach nearly to the northern border of the Embayment area, and again it may fall far short of that.

The next formation above the Eutaw sand is the Selma clay. In Alabama and Mississippi this formation is known as the Selma chalk, but before reaching Tennessee it loses its chalky nature, and becomes a clay that in places contains large numbers of fossil shells. The clay is leaden gray, green, or blue, depending partly upon whether it is wet or dry or unaffected by the weather, and partly upon its somewhat different composition in different parts. Its thickness in Tennessee, as given by Dr. Glenn, is from 100 to 275 feet.‡

This formation can be seen at the surface in Tennessee only in a belt from 6 to 8 miles wide, just west of the one where the Eutaw is exposed. Like that formation, it is covered to the

*U. S. Geological Surv. Water Supply and Irrigation Paper, No. 164, p. 25.

†Unpublished tentative correlation table by L. W. Stephenson, U. S. Geol. Surv.

‡*Loc. cit.*, p. 26.

Digitized by Google

west and north by younger formations, and like the Eutaw it probably covers the Embayment westward to southwestern Arkansas, where it is known as the Annona chalk.† It probably extends northward well toward the head of the Embayment.

Unless this formation becomes more sandy in the middle of the Embayment than in the area where it outcrops in Tennessee, it could not be expected to contain oil or gas; but it would form a good cover to seal in such of these products as might occur in the Eutaw sand beneath.

The formation above the Selma clay is the Ripley‡ This is described by Dr. Glenn as bearing a close resemblance to the Eutaw sand, inasmuch as it is composed of sand containing beds of clay. The clay beds are reported by him as being 10 to 20 feet or more thick. Many of them contain lignite in small pieces or thin beds, and leaf remains are common.

This formation extends across Tennessee, entering the state from Mississippi on the south, and passing into Kentucky on the north. Dr. Glenn thinks it is probably 500 feet thick in the southern part of Tennessee and says it is reported to be 400 feet thick at Wickliffe, Ky. As it is composed largely of loose sand, it should form a good reservoir for oil or gas, at such points as the other conditions for those products obtain, if they obtain anywhere.

Tertiary formations.—As above stated, the sea withdrew from at least a large part of the Embayment area, after the Ripley formation, the last of the Cretaceous ones in Tennessee, was put down. The land thus formed remained such for a long period of time, during which it was partly removed by running water. After this land period, the sea again advanced, and put down upon the old surface, a deposit known as the Porters Creek formation. Dr. Glenn* says that "the formation is composed mainly of fine-grained clay that is very dark

†Correlation by L. W. Stephenson, U. S. Geol. Surv.

‡This recently has been redefined by Stephenson, U. S. Geological Survey, Professional Paper 81. Stephenson puts the lower part of the Ripley, as defined by Glenn (Water Supply and Irrigation Paper No. 164, p. 27), in the Eutaw and the upper part he calls the McNairy sand; but for convenience, Dr. Glenn's definition is here used.

**Loc. cit.*

Digitized by Google

gray, or in places almost black, when wet, but which becomes a light gray on drying". He gives its thickness at Jackson, Tennessee, as about 175 feet, and considers this the best measurement available. This formation shows at the surface in Tennessee, in a belt from 4 to 8 miles wide, just west of the Ripley area. Paris and Huntingdon stand near the western border, and Henderson is on the line between this formation and the Ripley. Northward, it passes on into Kentucky, and southward into Mississippi.

The Porters Creek formation is covered by the Lagrange formation. According to Dr. Glenn's description, "The formation consists of interbedded sands, clays, and lignitic material. Much the larger part is sand, which is mostly fine-grained, though here and there throughout the formation beds of medium or coarse sand or even gravel may be found. Such coarse beds do not seem to be continuous over any large area".

Regarding its thickness, Dr. Glenn says, "In the deep well at Memphis, the Lagrange is 963 feet thick. The well at Dyersburg penetrated 678 feet of it and one at Hickman 750 feet without in either case reaching its base. In the Jackson well, near the top of the formation, its base was reached at a depth of 160 feet. At Wickliffe it is 430 feet thick and at Cairo 325 feet." It appears that the thickness of the formation, as shown in the Memphis well, may safely be relied upon for that part of the state near the Mississippi River.

If we disregard the loess, which, with the exception of the alluvial bottoms, covers an area about 30 miles wide east of the Mississippi River, and the thin surface mantle known as the Lafayette formation, the Lagrange formation covers the surface of all that part of Tennessee west of the Porters Creek; and like the Porters Creek and Ripley, it extends northward into Kentucky and southward across Mississippi.

AGGREGATE THICKNESS OF THE WEST TENNESSEE EMBAYMENT FORMATIONS.

Taking the thickness of the Eutaw sand as 275 feet; of the Selma clay as 375 feet; of the Ripley as 500 feet; of the Porters Creek as 175 feet; and of the Lagrange as 963 feet, the total thickness below the Lafayette is 2288 feet. This estimate, of

Digitized by Google

course, applies to those areas where all the formations occur, as they quite certainly do in southwestern Tennessee, and as is indicated in the Reelfoot Lake area, by the depth of the well south of Samburg. If wells should be put down on or a short distance east of the bluffs of the Mississippi, there should be added to this, perhaps 10 feet for the Lafayette and on an average of 50 feet for the loess, making a total thickness of approximately 2348 feet. One of the wells at Memphis was sunk 2517 feet without reaching the old rock floor, which indicates, as elsewhere mentioned in this paper, a thickening of the Cretaceous in the middle of the Embayment.

STRUCTURE OF THE AREA.

As will be seen by reading the preceding article in this number of the *Resources*, the occurrence of oil or gas in any area depends largely upon the structure, or the lay of the formations occurring beneath the surface; and as the Reelfoot Lake district is a part of the Embayment area, its structure can be understood only when taken in connection with that of the whole area.

In Tennessee, the general dip of the formations described above is to the west. According to the observations of Dr. Glenn* this does not much exceed 20 feet to the mile. In Kentucky, the dip swings around to the southwest, in Illinois to the south, and in Missouri and Arkansas to the southeast and east. It will thus be seen that the formations of the Embayment area lie as a wide trough, the sides of which slope in a general way toward the Mississippi, though the lowest part of the trough may not be on the present line of the river; and that the Reelfoot district, situated as it is near the head of the Embayment area, is in the focus of the southwest, south, and southeast dips of that part of the Embayment area in Kentucky, Illinois and Missouri.

The above is the general structure in the Embayment area. As to smaller structural features, it will be recalled that since the early deposits of the area were formed, there have been

*Loc. cit.

Digitized by Google

ERRATA

Fig. 3, page 31, should be inverted.

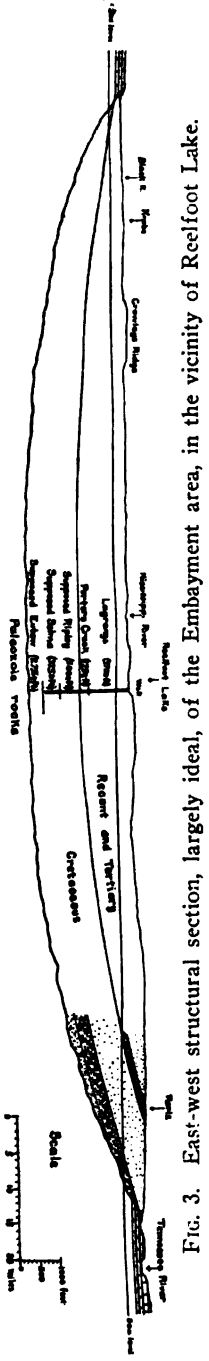


FIG. 3. East-west structural section, largely ideal, of the Embayment area, in the vicinity of Reelfoot Lake.

several recessions of the sea from the land. As above stated, one of these recessions took place at the close of the Lower Cretaceous, one at the close of the Upper Cretaceous, and several during the Tertiary. Between these, there were the corresponding advances of the sea upon the land. A retreat of the sea is usually taken to mean an elevation of the land, forcing the shore lines seaward. The other possibility is that the ocean bed may subside, causing the shore line to retreat, or the ocean-bed may rise, causing the shore line to advance. Many of the geographic changes of the past certainly have been due to the one cause and probably some of them to the other. In the case of the Embayment area, the evidence is strongly in favor of at least the more important of geographic changes having been produced by elevations and subsidences of the area itself.

Whether the changes from sea to land and back again, came from oscillations of the area itself or changes in the bed of the ocean is of great importance in considering the possibilities of gas and oil within the area. For if they were due to rising and lowering of the land (both very slow processes), it must have followed, as shown by the rocks of all land areas, that some parts moved more than others, while the general movements were in progress. If so, this meant a bending of the beds making up the different formations above described, and this resulted in the formation of anticlines and synclines; and this in turn formed reservoirs in which oil and gas might collect.

Digitized by Google

If on the other hand, the advances and withdrawals of the sea were due to changes in the sea level, the rocks of the area would not be flexed, for they would have been left quiet through the changes in geography.

Such anticlines and synclines as may exist probably had their inception during the elevation that followed the Lower Cretaceous deposition, and were enlarged during those that followed the close of the Upper Cretaceous and the Tertiary. For it is a principle of geology pretty well established that a fold beginning in any period of movement is intensified during subsequent similiar movements. High folds with strong dips can not be expected in the Reelfoot Lake district, or elsewhere in the Embayment area. The anticlines, if they exist, are low and flat.

The formations of the Embayment area that may contain oil and gas are covered with more recent ones, so that it is very difficult to locate such folds as may exist without many more deep well records than are now to be had. In fact with our present knowledge, the location of the folds and consequently of promising well sites, seems impossible except perhaps in limited areas. The only criteria in conjecturing their shape is in the structure of the older rocks surrounding the Embayment area. In those along and east of the Tennessee River in Tennessee and in those bordering the Embayment area in Kentucky, Illinois, Missouri and northeastern Arkansas, the folds are not in elongated anticlines and synclines, but are more nearly in the shape of domes and intervening basins. In central and southwestern Arkansas, the folds in the old rocks west of the Embayment are distinct east and west anticlines and synclines.

With these facts in mind, the geologist in directing pioneer oil and gas prospecting in the Embayment would proceed on the hypothesis that the folding in the area being drilled would be similiar in shape to that of the nearest old rocks on the border. The floor of the Embayment area is the continuation of these old rocks and their structure probably was transmitted to the new ones above, in times of its oscillation.

Digitized by Google

WELLS OF THE EMBAYMENT AREA.

Because the geology of the Reelfoot district is similiar to that of at least the northern half of the Embayment area, light may be thrown on the possible oil conditions of the former by taking a glance of what is known of the latter. That is what has been attempted in this paper. If the wells of the area were numerous enough, deep enough and well enough distributed, they would disclose the structure, which is the needed information in locating wells for oil and gas; but they are not numerous, not many are deep and such deep ones as have been put down are near the central line of the area.

Numerous wells have been sunk at Memphis for a city water supply, but as a rule these have stopped in the Lagrange formation, and are less than 1,000 feet deep, though at least one has gone to the depth of 1,583 feet. If any of them have reported gas or oil, the writer is not aware of it.

From 1909 to 1911 four wells were put down for oil and gas, on an island that then lay just west of Loosa Hatchie and Wolf rivers at Memphis. The writer is informed that since that time the course of the Mississippi has so changed as practically to remove that part of the island where the wells were sunk. These wells are respectively 1,793 feet, 1,017 feet, 1,250 feet and 2,517 feet deep.* It appears that all of them produced a small amount of gas, and possibly some of them a little oil.

At this writing, a well is being sunk, with a rotary drill, on the east side of Reelfoot Lake, a mile and a half south of Samburg, under the direction of Mr. J. W. Scott of Pittsburg, Pennsylvania. As yet, no log of this well has been furnished this Survey; but when last visited by the writer, Nov. 11, 1915,

*For a full description of wells Nos. 1, 2 and 3, see Munn, M. J., *Resources of Tennessee*, Vol. II, No. 2, pp. 48-68. Well No. 4 was not completed when Mr. Munn's paper was prepared. Concerning well No. 4, Mr. C. H. Trimble, of Memphis, stated in a letter to the present writer that there were "showings of what appeared to be gas at many places on the way down, and there was apparently gas at the lowest depths reached. There were also several showings of what the driller pronounced to be oil, but nothing commercial." As to the material passed through, Mr. Trimble says, "I have not the log of this latter well, but it was put down to a depth of 2517 feet, and stopped in clay very much like the Porters Creek clay." The well was sunk with a rotary drill.

Digitized by Google

it was reported by Mr. Scott to be approximately 2,000 feet deep. The drill was in very tough, dark blue clay that the drillers called gumbo. Mr. Scott said that at 270 feet, a 2-foot oil sand was struck that he thought would produce five barrels of oil a day; that from 1,230 to 1,457 feet, the drill passed through sand with a showing of oil all the way, but especially in its upper and lower 30 feet; and that a little gas was struck in the upper 30 feet of the sand. He estimated that the total output from the sand would be from 20 to 30 barrels a day.

Mr. M. J. McGinnis, City Clerk of Caruthersville, Missouri, stated in a letter that a well was sunk there 1,550 feet for water, and that no indications of oil or gas were found in drilling.

Mr. J. W. Rhores, Jr. of Osceola, Ark., reports that the water supply for that city comes from the depth of 1,450 feet; for Wilson, Ark., from a depth of 1,690 feet; and from Marked Tree, Ark., from 2,200 feet. So far as the writer is informed, none of these showed indications of oil or gas.

DIFFICULTY IN LOCATING WELLS.

In areas of old rocks, such as those surrounding the Embayment area, the geologist can, with comparative ease, locate the places where oil or gas might be secured and the areas or localities where there is no chance for them. In most areas, such as Middle Tennessee, most of Kentucky, Pennsylvania, West Virginia, Oklahoma, or that part of Arkansas west of the Embayment area, an operator would be very foolish to put down a well without the advice of a competent geologist. But in the Embayment area, where almost the entire surface is so completely covered with recent deposits as to hide all the usual indications of the structure, the work of a geologist in locating prospective wells would be difficult and might prove futile. As has been suggested to the writer by Dr. Glenn, it is possible that a study of the bluffs from Hickman southward to Memphis might reveal a north-south difference in structure; and that light might be thrown on the structure away from the river by careful use of railroad and drainage profiles.

While a large number of deep well records would be of the greatest assistance of any data that future developments may

Digitized by Google

furnish, these must be used with the fact in mind that a period of erosion followed the deposition of both the Lower and the Upper Cretaceous beds. In other words, these have been in part removed, and in this the tops of the folds probably suffered most. This being true, a well on an anticline might not reach one of these formations at a less depth than a neighboring one on a syncline. Especially could this be true if the folds are comparatively small.

At present, the only suggestions the writer can give prospectors in the Tennessee part of the Embayment area are to keep well away from its borders, locate near railroads where supplies are easily obtained, and when the well is once started go to the old rock floor before stopping.

CONCLUSIONS.

1. The formations of the Embayment area probably contained enough organic matter at the time of their deposition to produce a good supply of oil and gas.

2. Around the edges of the Embayment area, where the formations are exposed, they consist of alternating beds of sand and clay. The deep wells that have been sunk at Memphis and Reelfoot Lake indicate that beds of sand, though fine-grained, occur at practically all depths penetrated by the wells. These sand beds, lying as they do, between beds of clay, should form gas and oil reservoirs if the beds are folded.

3. The elevations and depressions that have occurred in the area make it probable that slight folding has taken place.

4. While none of the four wells sunk at Memphis produced oil or gas in commercial amount and while the one on Reelfoot Lake has not as yet been proved to be a commercial well, the reports show that all these produced gas in small amount and some of them made good showings of oil. This, if the drillers were not mistaken, proves the presence of these products, and if they exist at all it stands to reason that in places they may occur in paying quantities.

5. The deep well records at Memphis and Reelfoot Lake indicate that the Cretaceous deposits thicken in the middle of the Embayment area. This is not surprising, for it is this part of the area that probably was first occupied by the sea in both

Digitized by Google

Lower and Upper Cretaceous times, and equally probable that it was the last to be vacated. Granting that these conditions were true, it was the area of longest deposition, and consequently the thickest deposits should be expected there.

6. As above stated, any well started should be sunk to the old hard rocks upon which the Cretaceous beds rest, unless commercial amounts of oil or gas should be struck before that depth is reached. To the present, no prospective gas or oil well has reached these old rocks, but their top is probably not very far below the point reached in the deepest drill hole at Memphis and in the one at Reelfoot Lake.

7. It must be understood that no assurance can be given of a successful well in an undeveloped area, but if prospecting should be continued in the Reelfoot district, the low flat anticline described by Mr. Fuller* as the Tiptonville dome should be the guide to it. The wells should be sunk near a straight line beginning some 4 miles south of Tiptonville and running just east of that place, toward New Madrid. The northern limit of the area is about half way between the State line and New Madrid, in the loop of the river.

8. The Caddo oil field of northwestern Louisiana is located on a structural dome, and the oil comes from the Upper Cretaceous† the deposits which are similar in character to those of Tennessee. This lends encouragement to the formation being oil bearing in Tennessee, provided the necessary structural conditions occur.

9. The formations considered in this paper are those of Cretaceous and Tertiary age. As far as our knowledge of them goes, it is not impossible for the old rocks that form the floor of the Embayment, in places to contain oil and gas; but the difficulty in locating wells in them is even greater than in the younger rocks above.

---

*Loc. cit.

†Harris, G. D., U. S. Geol. Surv., Bull. 429, pp. 127-8.

Digitized by Google

An Interesting Case of Spontaneous Combustion

By Paul C. Bowers.

The burning of a large pile of black shale dumped at the edge of the Tennessee River, a little south of Hamburg, has caused considerable excitement and interest in Hardin County because of its spontaneous origin, and long duration. A description and explanation of this rather remarkable incident may be of interest to the readers of this publication.

The U. S. Government has been dredging the shallow place in the Tennessee River south of Hamburg and a canal, about two miles long, has been excavated out of the rock in the bed of the river. The rock was piled in the water at the edge of the river and consisted mostly of limestone, but for a distance of about a hundred yards the pile was the typical Chattanooga shale. This shale contained a great deal of bituminous matter, even a few pieces of thin lenses of coal, some oil and a considerable quantity of pyrite and marcasite.

Pyrite and marcasite are chemical compounds of iron and sulphur. They both have a pale brass-yellow color and resemble each other very closely. Marcasite is more easily decomposed than pyrite and nearly always has a greenish-white, varying to white, powder on its surface. This powder is a mineral, known as melanterite, sometimes called vitriol or copperas. Its chemical name is sulphate of iron. It is soluble in water and tastes like a mixture of iron and alum. This is the first decomposition product of marcasite and pyrite.

About the 15th of August, 1915, after several days of rain and high water this pile of black shale started burning just above the high water mark. The fire continued over a period of about two months extending along the pile for a distance of seventy-five yards. It was a slow smouldering fire and when fanned by the wind would burst into flames. There was a constant cracking noise which was due to the cracking of the shale by the gas formed on heating the pyrite. Sulphur fumes were very strong, and, as reported by Mr. Bruce Wade, who was doing geological work in this area at the time, the odor was

Digitized by Google

detected at a distance of some miles. They attacked the paint on the Government boats and turned it to a dirty color because the lead carbonate of the paint was changed to a sulphide. These fumes also killed the leaves on the trees nearby. A thin coating of sulphur was formed on the surface of the shale dump. Considerable melanterite or copperas has also been formed in the burned portion of the dump.

In order to explain the cause of this phenomenon a little physical chemistry must be considered.

Oxidation in the strict sense of the term is a chemical change in a substance whereby the substance unites with oxygen, which generally comes from the air. This is the change by which iron is converted into iron rust, and wood, coal, and other carbonaceous materials are converted into carbon dioxide, when they burn. All combustible substances under ordinary conditions are constantly being oxidized at the surface and when oxidation takes place, heat is always formed. But the oxidation is so slow that the heat formed is radiated and lost as fast as it is formed. When heat is applied to the substance, the rate of oxidation is increased. When the oxidation is so rapid that light and heat, perceptible to the senses, are evolved, the substance is said to burn or undergo combustion. Combustion is, therefore, rapid oxidation.

When a substance is oxidized at the natural, slow, gradual rate and when conditions are such, that the heat produced by this oxidation is not radiated and lost as fast as produced, the heat accumulates and thus increases the rate of oxidation. This in turn causes more heat to be formed; which again causes more oxidation; and in this way, the oxidation of the substance finally becomes so rapid as to cause the substance to burn. When all this takes place without external aid, we have spontaneous combustion.

Oxidation takes place more rapidly in the presence of moisture, or in a moist atmosphere than under dry conditions. In fact oxidation is so slow in a dry atmosphere that it may hardly be noticed. Oxygen in large quantities is found dissolved in rain water and fresh water, such as is present at flood time, as a result of its fall through the air. Analyses of rain water show that about 30 per cent of the dissolved gases is oxygen. Thus

Digitized by Google

in rain water, oxygen is in its most active form under natural atmospheric conditions, and oxidation of combustible matter takes place more rapidly in its presence.

This pile of black shale had all of the conditions and essentials for spontaneous combustion. The high content of combustible material in the shale, such as marcasite, pyrite, oil and bituminous matter, furnished the fuel for the fire. The rain water with its high oxygen content and the air slowly circulating through the pile, supplied the oxygen for oxidation. The shale was a poor conductor of heat so that the heat from

Burning of Chattanooga shale in the Tennessee River near Hamburg, from spontaneous combustion.

oxidation was not lost through radiation but accumulated within the pile.

The marcasite in a finely divided condition and, to a less extent, the pyrite, was very readily oxidized by the moist air and by the rain water with its high oxygen content, clinging to the surface of the marcasite just above the water line. This was the starting point of the spontaneous combustion. The heat produced by the oxidation of the marcasite was retained by the shale and thus enhanced the oxidation. In this way the rate of oxidation kept increasing and the heat accumulating. As the

Digitized by Google

temperature rose, the other combustible materials were oxidized, and when it reached a certain temperature, the oil ignited. Then all the combustibles burned and we had the phenomenon of spontaneous combustion.

In the complete oxidation or combustion of pyrite and marcasite, iron oxide or rust and the gas, sulphur dioxide, are formed. This gas is largely the sulphur fumes given off in the burning of the shale and is the same as that given off from a burning sulphur match. It attacked the leaves of the trees, etc., and caused the offensive odor of the burning shale. It is soluble in water, and because there was a great deal of moisture on the shale, this gas was dissolved, and caused all the shale to have an acid taste.

A small amount of sulphuretted hydrogen gas was formed by the action, in the presence of moisture, of the sulphur dioxide, from the burned pyrite, on the pyrite of the shale, which had not yet burned. This was the gas of the fumes which attacked the white paint on the boats and changed some of the white lead carbonate of the paint to black lead sulphide, thus causing the dirty color.

When the supply of oxygen is rather limited, as was the case in some parts of this pile of shale, the marcasite and pyrite are only partially oxidized. In this case iron sulphate and free sulphur would be formed. The heat volitilized the sulphur, which, on cooling at the surface, condensed, and was deposited as crystals and yellowish white powder on the surface of the pile of shale. The iron sulphate left behind in place of the pyrite or marcasite, on cooling took up water and formed crystals of green vitriol or copperas. These crystals, however, on exposure to the air, lose some water and crumble to a white powder, which was its form in the burned shale.

The burning of shale is no ordinary occurrence but is possible when there is a large amount of combustible material in it. The spontaneous combustion of shale, however, is very rare, and this phenomenon is worthy of record.

Digitized by Google

Sketch of the Work Done by the State Geological Survey in 1915

In the first part of the year Mr. Dandridge Isom was employed in keeping logs of oil wells in the Oneida district, Scott County. During the summer, Mr. H. F. Bain was employed to do this work.

In co-operation with the U. S. Bureau of Mines and the U. S. Geological Survey, something like four hundred coal samples were taken for analysis, and the analyses were made at the laboratory of the Bureau of Mines at Pittsburg, the chemist of the Survey, Dr. Paul C. Bowers, assisting in the work. Dr. L. C. Glenn, in charge of the coal work, spent something like a month in the field, and the remainder of the summer until October in the preparation of the report on coal.

Mr. C. R. Watkins, Jr., F. W. Farnsworth, and A. P. Miller were engaged in the field work for a map of McNairy County, which was completed; and in the mapping of a part of Hardin County, and a part of Decatur County. In September Mr. Watkins was transferred to Shelby County where he is yet employed. Mr. Farnsworth was employed during March and April, and Mr. Miller from June until September. These county maps are intended as bases for geological and soil maps.

In co-operation with the Agricultural Experiment Station, University of Tennessee, Messrs. G. M. Ferris and F. M. Maloney were employed during the summer in the preparation of a map of Rutherford County, also to serve as a base for soil and geological maps.

Beginning with May, Mr. Bruce Wade was employed until October on geological work in McNairy and Hardin counties, having finished the former.

Beginning with June, Dr. J. J. Galloway and H. N. Coryell were employed, in co-operation with the Agricultural Experiment Station, University of Tennessee, in mapping the geology of Rutherford County, which was completed.

Digitized by Google

Until July, Mr. O. P. Jenkins was employed in the preparation of a bulletin on the correlation and general description of the geological formations of Tennessee. Beginning with July, he was sent to Johnson County to investigate the new phosphate discoveries of that locality, which work kept him until November. Since that time, he has been employed in the preparation of a report upon these phosphates.

Beginning with September, a soil survey of Shelby County was undertaken, in co-operation with the U. S. Bureau of Soils, Mr. R. T. Allen being put in charge of the work. This is still in progress.

During the year Dr. C. H. Gordon has put in such time as he could spare from his duties as Professor of Geology in the University of Tennessee, in the preparation of a bulletin on the marbles of Tennessee.

During the whole of the year, with the exception of the time required for trips to investigate general forest conditions in different parts of the State, Mr. R. S. Maddox, Forester, was employed in efforts toward the reclamation of gullied lands in West Tennessee. Most of his time was consumed in the field in direct touch with the farmers who own the waste lands, though he has written a few articles for publication.

Dr. Paul C. Bowers, the chemist of the Survey, has been employed in making coal analyses, phosphate analyses, and in doing such other general chemical work as has been required of the Survey.

Miss Elizabeth Cockrill spent such time as she could spare from her duties as secretary, in the preparation of a bulletin on elevations in the state.

The administrative report of the State Geologist appeared in the early part of the year. Four issues of the "*Resources of Tennessee*" were published, containing articles on the economic mineral resources of the state. A map of Lewis County, showing iron banks and mines, the streams and the cultural features was published, as was also a geological map of the state.

A. H. P.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Digitized by Google

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Maps—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 10 cents.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

Digitized by Google

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Digitized by Google

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

Vol. III. No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

Vol. III. No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

Vol. III. No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

Digitized by Google

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

Vol. V. No. 1—The Hydro-Electric System of Tennessee, by J. A. Switzer.
West Tennessee Gullied Lands and Their Reclamation, by R. S. Maddox.
The White Phosphates of Tennessee, by J. S. Hook.

No. 2—Physiographic Influences in the Development of Tennessee, by L. C. Glenn.
Care and Protection of Forests, by R. S. Maddox.
Two Natural Bridges of the Cumberland Mountains, by Wilbur A. Nelson.

No. 3—The Iron Ore Deposits of Lewis County, Tennessee, by Reese F. Rogers.

No. 4—The Soils of Tennessee, by C. A. Mooers.
Recent Development near Oneida, Scott County, Tennessee, by L. C. Glenn.

The supply of Vol. 1 No. 2, Vol. III No. 1, and Vol. V No. 1, is exhausted.

Digitized by Google

ACCESSIONED NOV 8
RECEIVED
NOV 24 1916
UNIV. OF MICH.
LIBRARY

VOLUME VI NUMBER 2

TN
24
T2
A4

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY AND OCTOBER
BY THE
STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

APRIL, 1916

CONTENTS

Phosphates and Dolomites of Johnson County, Tennessee. . . . C. P. Jenkins
Structure of the Southern Part of Cumberland County, Tennessee, in Relation to the Possible Occurrence of Oil and Gas. . . . . Charles Butts
Notes on Manganese in East Tennessee. . . . . A. H. Purdue

Entered as second-class matter January 10, 1913, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

1909—

VOLUME VI NUMBER 2

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey
NASHVILLE, TENNESSEE

APRIL, 1916

State Geological Commission

Gov. TOM C. RYE, *Chairman*

DR. BROWN AYRES, *Secretary*
President, University of Tennessee

H. KNOX BRYSON
Commissioner of Agriculture

DR. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

R. A. SHIFLETT
Chief Mine Inspector

Geological Corps

A. H. PURDUE
State Geologist

OLAF P. JENKINS
Assistant Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

CONTENTS

Phosphates and Dolomites of Johnson County, Tennessee.....O. P. Jenkins

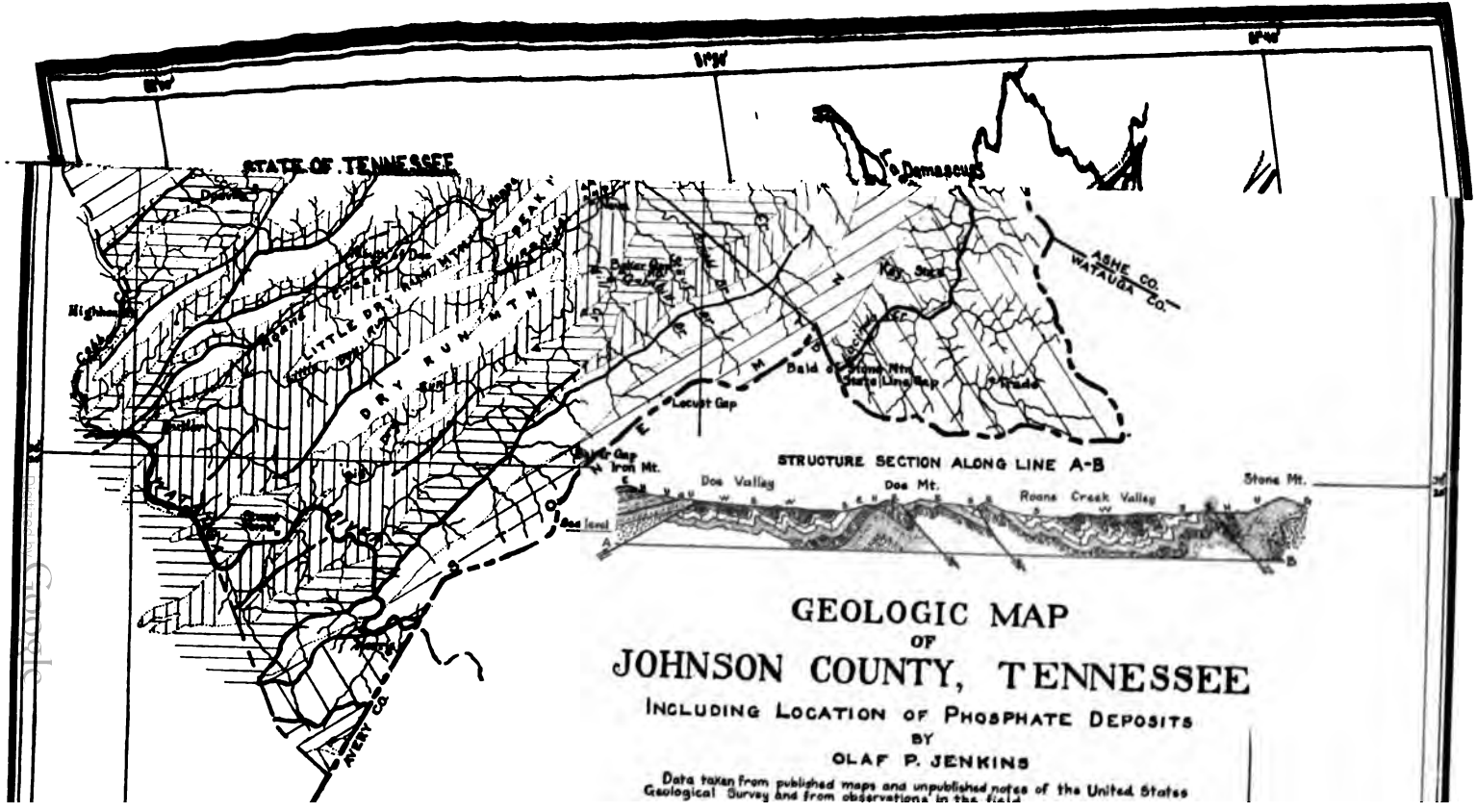
Structure of the Southern Part of Cumberland County, Tennessee, in Relation to the Possible Occurrence of Oil and Gas.....Charles Butts

Notes on Manganese in East Tennessee.....A. H. Purdue

Digitized by Google

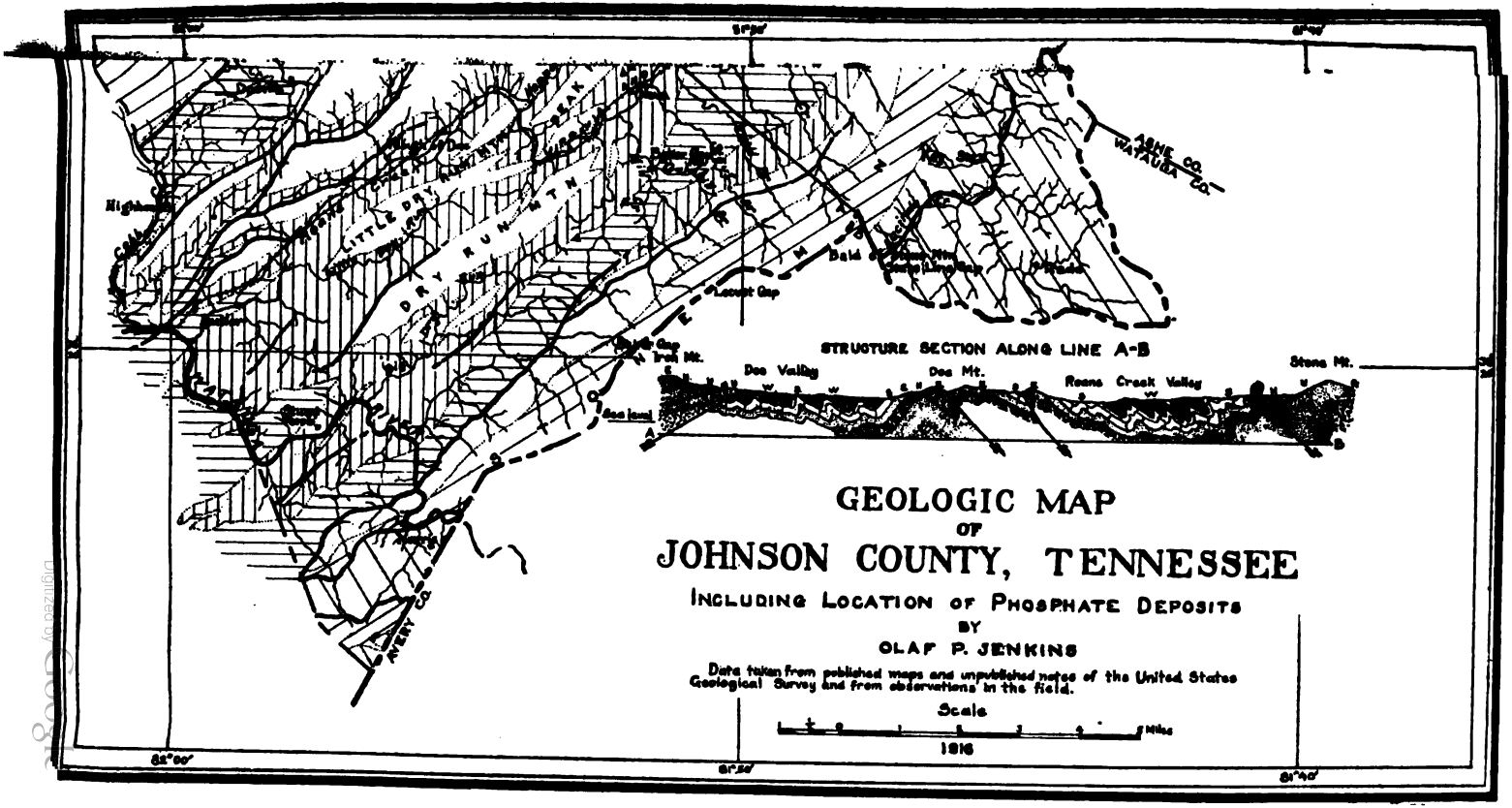
TN
24
.T2
A4

Digitized by Google


STATE OF TENNESSEE
Damascus
ASHE CO.
WATAUGA CO.
Key Stock
Bald
Stone Mtn.
State Line Gap
Locust Gap
Iron Mt.
Doe Valley
Doe Mt.
Roans Creek Valley
Stone Mt.
STRUCTURE SECTION ALONG LINE A-B
GEOLOGIC MAP
OF
JOHNSON COUNTY, TENNESSEE
INCLUDING LOCATION OF PHOSPHATE DEPOSITS
BY
OLAF P. JENKINS
Data taken from published maps and unpublished notes of the United States Geological Survey and from observations in the field

TN
24
.T2
A4

Digitized by Google



GEOLOGIC MAP
OF
JOHNSON COUNTY, TENNESSEE

INCLUDING LOCATION OF PHOSPHATE DEPOSITS

BY

OLAF P. JENKINS

Data taken from published maps and unpublished notes of the United States Geological Survey and from observations in the field.

Digitized by Google

Phosphates and Dolomites of Johnson County, Tennessee

By Olaf P. Jenkins.

INTRODUCTION.

A new field of phosphate, entirely distinct from the well known deposits of Middle Tennessee, was recently discovered in Johnson County in the northeastern corner of the State. Without doubt the product of this new field will fill a local need in the form of ground raw phosphate rock; and probably in the future it will prove commercially valuable, especially as the present available supply of this fertilizer product may diminish. Further careful prospecting is necessary in order to estimate the probable extent and value of the deposits and possibly one or more typical deposits may have to be mined in order actually to determine their commercial value, which may then be used as a comparison in estimating the value of the whole field. It is impossible to determine from the surface exposures and indications, or from the amount of prospecting already carried on, the extent of the material, since the deposits are extremely irregular.

The study of the nature and occurrence of the material should be of interest to those who make a study of phosphates in general.

The general occurrence of the phosphate deposits is in the foothills of high mountains overlooking excellent farming lands in level valleys. As residual deposits, they are associated with magnesian limestones or dolomites.

SITUATION AND TRANSPORTATION FACILITIES.

Johnson County is situated in the extreme northeastern corner of the State, bounded on the north by Virginia, on the east by North Carolina, and lying in the heart of the Appalachian Mountains. Mountain City is the county seat. It is the term-

Digitized by Google

inus of two railroads, a broad-guage (Virginia and Southwestern Railroad, owned and operated by the Southern Railway), which enters the county from the southwest, coming from Bristol by way of Elizabethton, and a narrow-guage (Laurel Railway, locally known as the "Peavine"), which runs from Damascus, Virginia, about 14 miles to the north. The only other railroad in Johnson County is a broad-guage (Beaverdam Railroad), which runs from Damascus into Shady Valley, a cove lying between Iron and Holston mountains. These railroads were built primarily to take out timber, which previously existed there in great quantities. Many local branch roads were also built, but most of these have since been torn up. Another object of the railroads and the several branch lines was to remove iron ore from certain limonite deposits then mined. Now the lumber business has died down and the iron mining is at a standstill. For this reason the people are very receptive to any new enterprise and are anxious to develop the phosphate industry if this material proves worth mining.

ACKNOWLEDGMENTS.

The commercial analyses contained in this paper were made by Dr. Paul C. Bowers, Chemist of the State Geological Survey, with the exception of certain early samples collected by the State Geologist and analyzed by Mr. Victor Lee, Acting Chemist in the absence of Dr. Bowers, and one specimen collected by Dr. J. H. Pratt and analyzed in his laboratory in Tampa, Fla.

To Dr. Bowers the writer is also indebted for the six complete analyses of typical specimens of phosphate, for a report in which these analyses are discussed, and for valuable suggestions and information regarding the chemical problems encountered in the work.

The writer acknowledges, with thanks, the work of Dr. E. E. Reinke, head of the Biology Department at Vanderbilt University, who, with Dr. Bowers, made microphotographs of thin slides taken from typical specimens. The slides were ground by Dr. Bowers.

Specific interest is added to this paper by the valuable mineralogical report contributed by Dr. Austin F. Rogers, Professor of Mineralogy and Petrography at Leland Stanford, Jr.,

Digitized by Google

University, whose generosity the writer acknowledges with thanks.

Both published and unpublished information on the geology of Johnson County provided by the United States Geological Survey has been incorporated in this paper.

The courtesy and co-operation of the citizens of Johnson County facilitated the collection of information for this report.

DISCOVERY.

In January, 1915, a rock containing a black mineral of manganese was picked up by Mr. John Cress on the Baxter Gentry farm about 2½ miles northwest of Mountain City. It was taken by Mr. Cress to Mountain City for the purpose of arousing an interest in mining. Donnelley and Donnelley, attorneys at law, sent the rock to Froehling and Robertson, chemists of Richmond, Virginia, who reported that the specimen was phosphate rock. Of course the chemists referred to the yellow rock containing the manganese, but the senders thought they were speaking of the black manganese material itself. The chemists ran a quantitative analysis of the rock and reported 74.85 per cent bone phosphate of lime, and 2.02 per cent iron and aluminum oxide. This aroused the enthusiasm of the people and they immediately wrote to Washington and other places for literature on phosphate, and in this way learned to make the field test.* With this test they searched for the mineral in different places in the county; but as they had in mind that the mineral was black, their progress was retarded. Certain bluish-black rock on Senator E. E. Butler's land, 2½ miles northwest of Mountain City, reacted strongly to the field test and has since been found to contain 57 per cent bone phosphate of lime. Enormous quantities of bluish-green rock of somewhat similar appearance, which reacts slightly to the field test, occurs in a prominent bed on Iron Mountain and as cross-cutting dikes in the granite area east of Mountain City. These rocks caused keen excitement until analyses proved them to contain only 1 or 2 per cent bone phosphate.

*This test is made by placing a little crystalline ammonium molybdate on the rock and adding dilute nitric acid. A yellow precipitate of ammonium phosphomolybdate is formed if the rock contains phosphorus.

Digitized by Google

Late in the summer, prospect pits were opened at several localities. Although this prospecting was quite incomplete, it threw new light on the quality, occurrence, and nature of the material.

OCCURRENCE OF THE PHOSPHATE ROCK.

The phosphate rock in Johnson County occurs generally as a concentration from weathered residual material, the original rock usually being dolomitic limestone. A large number of the original bed rocks in the county, both igneous and sedimentary, contain more or less phosphatic material. With the exception of two formations mapped by the United States Geological Survey, as the *Shady limestone* and *Watauga shale*, most of them are of insoluble siliceous character.

The Shady limestone is a group of rock beds, which, though often quite siliceous, are largely composed of magnesian limestones, interbedded with shales. The Watauga shale is composed, for the most part, of varicolored shales interbedded with thin layers of magnesian limestone. These two groups are more or less phosphatic, especially in the beds lying near the contact between them. Those beds near the contact show an intergradation between the Shady limestone below and the Watauga shale above. In somewhat soluble rocks such as these, concentration of insoluble minerals, even though they occur in very small percentage in the original beds, is more likely to take place than in less soluble rocks in which the percentage of the mineral may be higher. Calcium carbonate and magnesium carbonate, the main constituents of limestones and dolomites, are quite soluble in comparison with other minerals in the rocks, and while they are leaching out, the others are accumulating by concentration. This is the case in Johnson County, for accumulations of different sorts are found where the conditions have been favorable to the leaching of the dolomitic limestones. Siliceous material such as flint, chert, and chalcedony, and minerals of iron, manganese, and phosphate, are less soluble than dolomite or limestone, and when those rocks contain them they may be concentrated under certain conditions of weathering.

The conditions under which this weathering can work most favorably are complicated. Long periods of time are neces-

Digitized by Google

sary for the accumulation of residual weathered material, while rapid erosion will carry away such accumulations. Thus very steep bluffs and rather recently eroded exposures do not show much in the way of phosphate rock. A condition that will promote weathering activity of percolating surface waters is the jointed and fractured state of the rocks. In Johnson County the dolomitic limestones and the more brittle shales contain numerous cracks and fissures which cut through the beds at various angles. They also contain in abundance veins which are simply old cracks now filled by minerals which have been carried into them and deposited by the action of circu-

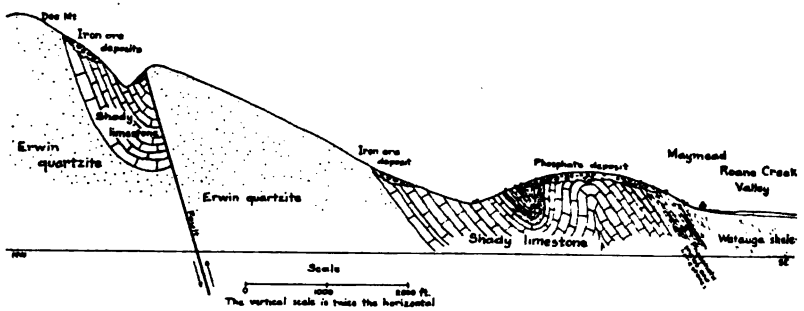


FIG. 1. Structural section, partly hypothetical, across a region near Maymead, showing the relation of the iron ore and phosphate deposits to the underlying geological formations.

lating waters. Besides these larger cracks there are much smaller ones. This condition is very pronounced in the dolomitic limestones of Johnson County, and is manifested by their extremely brecciated conditions. The breccias in this case consist of highly fractured rock, broken up to small angular fragments, the fragments recemented by some mineral, such as quartz, calcite or dolomite.

The structure of the rock beds in this region is complicated, but has a system, although the layman would not recognize it. The beds have been thrown into a series of folds, faulted, broken, crushed, and twisted in many ways, but their general trend is northeast-southwest. The strata underlying the valleys are in the main *synclinal* or trough-like in their structure, while those forming the mountains are bowed up,

Digitized by Google

or *anticlinal.* Local folding complicates the structure and especially effects detailed work. In general, however, one may follow the main beds of phosphate deposits through the county from a study of the rocks containing them, and of their structural relations.

Since the phosphate occurs in the residual material of the Shady limestone and Watauga shale, it is interesting to note the extent of these geological formations in Tennessee even in parts other than Johnson County. The Shady limestone and

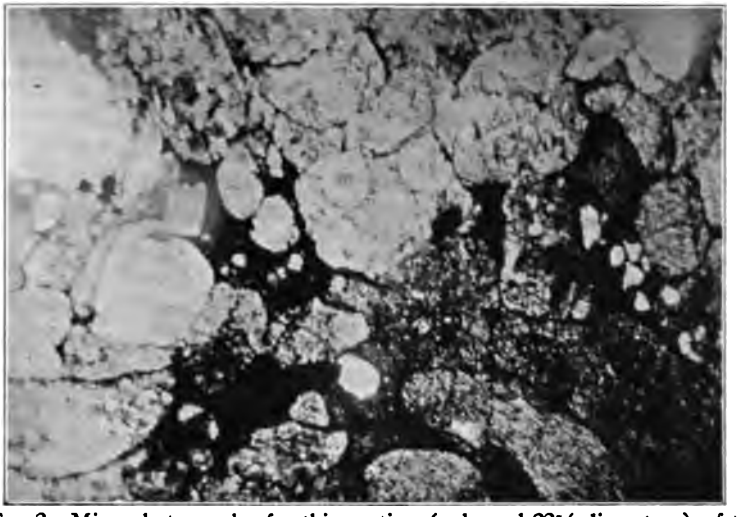


FIG. 2. Microphotograph of a thin section (enlarged 22½ diameters) of the oölitic phosphate rock from Senator E. E. Butler's place. Shows the general texture of the rock, made up of ovules cemented together. (E. E. R. and P. C. B.)

Watauga shale extend from Butler to Hampton in Carter County, to Unicoi, Erwin, thence southwest 4 or 5 miles into Unicoi County. These formations also occur northeast of Elizabethton and extend to Valley Forge and on towards Unicoi. They also occur in the southern part of Greene County, extending into Cocke County, south of the Meadow Creek Mountains. The exact extent of the formations may be found on maps of the United States Geological Survey.* It is not

*U. S. Geol. Surv. folios, Cranberry, Roan Mountain, Greeneville and Asheville, Nos. 90, 151, 118, and 116 respectively.

Digitized by Google

known, however, whether or not phosphatic deposits occur in these areas. In fact, this problem has not yet been investigated to so great an extent.

CLASSIFICATION OF THE PHOSPHATE ROCKS.

In order to distinguish the different phosphate rocks of Johnson County the following classification is suggested. The distinctions, it will be noted, are purely arbitrary. There is a gradation between the several forms of Class I.

Class I. Brecciated (generally yellowish, containing chert and particles of manganese minerals).

A. Varicolored, hard, phosphatic breccia (not decomposed) with a filling of stalactitic whitish minerals of phosphate.

B. Laminated form.

C. Weathered earthy form.

(1) Yellow and brown (occurring in chunks or "donnicks" and in small pieces all scattered through a residual mass—both hard and soft).

(2) Fragmentary, with thin coating of white acicular crystals of zeolite over each fragment.

This class is undoubtedly caused by the leaching of the more soluble calcium and magnesium carbonates from the dolomitic strata, and by the concentration of the less soluble lime phosphate. The lime phosphate, in places, has evidently itself been dissolved, but redeposited in the form of minerals of crystalline character, which, massed together, form small stalactitic fillings in cavities. The solvent for the lime phosphate may have been circulating carbonated waters or waters impregnated with organic acids derived from surface leaching of decayed vegetable matter. The presence of limestone may have been the cause of the precipitation. The transportation of the dissolved phosphate was probably only through short distances, perhaps only a few feet.

Digitized by Google

Class II. Oölitic.

Dark-blue rock of very limited extent, occurring on Senator E. E. Butler's place.

This is a chemical precipitate of calcium phosphate, formed in minute concretionary ovules, or oölites, possibly formed during the time when the sediments of the original beds were being deposited. Organic material is present in the phosphate rock.

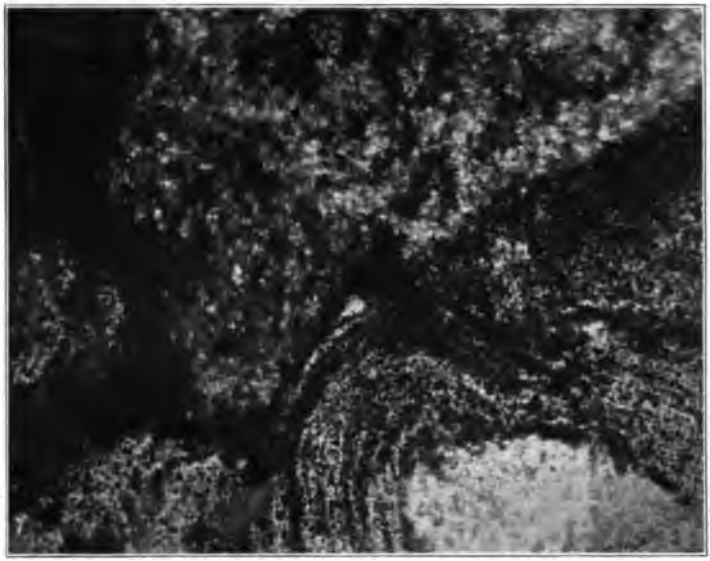


FIG. 3. Microphotograph of the same slide of rock section (enlarged 141½ diameters) as in Fig. 2, but with greater magnification. Note the concentric development in a concretionary ovule. (E. E. R. and P. C. B.)

CLASSIFICATION OF THE SLIGHTLY PHOSPHATIC ROCKS.

I. Those from which the phosphate rock were derived, usually brecciated.
   A. Limestones and dolomites.
   B. Siliceous dolomitic limestones and calcareous shales.

II. Those which may have been the original source of the phosphatic material in later rocks.
   A. Older sandstones, conglomerates and shales.
   B. Igneous rocks.

Digitized by Google

(1) Bluish-green basalt.
   a. Interbedded sheet on Iron Mountain (amygdaloidal basalt).
   b. Cross-cutting dikes in granite area.
(2) Granitic rocks.

MINERALOGY OF THE PHOSPHATE ROCKS OR PHOSPHORITES.*

A number of specimens of the Johnson County phosphate rocks were sent to Dr. A. F. Rogers, Professor of Mineralogy and Petrography at Leland Stanford, Jr., University in California, who has done special work on the minerals of phosphorites. Doctor Rogers very kindly determined the minerals present in the material with aid of the polarizing microscope, and submitted the accompanying report. It should be stated that his report was made without reference to the complete analyses which were finished subsequently. The writer's report also was made before Dr. Rogers's report was received. Doctor Rogers's suggestion as to the probable origin of the phosphorites—that of the replacement of shaly limestone or calcareous shale—seems to the writer quite possible from his observations in the field, applying especially to the more laminated forms, which, though often representing the better grade of phosphate, have much the appearance of shale. Besides, the phosphate rocks usually occur in residual material of the beds transitional from the dolomites of the Shady limestone to the shales of the Watauga formation.

The following is the report of Dr. Rogers:

"The Johnson County phosphorites are buff to light brown brecciated rocks made up of angular fragments which have a laminated structure. The main constituent of the phosphorite is the microcrystalline calcium carbonophosphate mineral called dahllite. The index of refraction of the dahllite is about 1.61 and the double refraction rather weak. Under crossed nicols of the polarizing microscope it shows aggregate polarization due to interlocking crystals. The cementing material of the breccia is a white, apparently amorphous mineral which proves

*The term *phosphorite* is the technical, or mineralogical, name applied to calcium phosphate material, commercially known as *phosphate rock* or simply *phosphate*.

Digitized by Google

to consist of two minerals, crystalline dahllite and amorphous collophanite, which is also essentially calcium carbonophosphate. The dahllite has an index of refraction greater than that of cinnamon oil (n=1.600) while the collophanite has an index of refraction less than cinnamon oil. Some of the phosphorites contain white incrustations in cavities and white seams traversing the rock. These crusts and seams have a fibrous structure and occasionally have minute six-sided prismatic crystals on their free surface. This mineral is dahllite.

FIG. 4. Microphotograph of a thin section (enlarged 22½ diameters) made of the phosphate rock from W. G. Nave's place at Neva. Note the incrustations lining the cavities. (E. E. R. and P. C. B.)

"Mechanical impurities present in the rock include quartz, limonite and a brownish-yellow pigment which gives the buff to brown color to the rocks. Needle-shaped crystals of a zeolite were found in one specimen.

"The phosphorite from the Senator E. E. Butler locality is a dark brown to black rock quite different from the other phosphorites. It consists principally of amorphous collophanite.

"Contrary to the statements found in the text books, phosphorites or phosphate rocks do not consist of massive apatite, but of crystalline dahllite and amorphous collophanite. These

Digitized by Google

two minerals are essentially calcium carbonophosphate or combined tricalcium phosphate and calcium carbonate with the formular $3Ca_3(PO_4)_2.CaCO_3$. Calcite seems to be absent from the Johnson County phosphorites. The calcium carbonate is chemically combined with the calcium phosphate.

"It seems probable that the microcrystalline dahllite, which makes up the bulk of these phosphorites, has been formed by the slow and gradual crystallization of collophanite, which in turn was formed by the replacement of shaly limestone or calcareous shale by means of calcium phosphate-bearing solutions."

DISCUSSION OF COMPLETE ANALYSES.*

Following is a report submitted by Dr. Bowers on the complete analyses made by him on typical phosphate rocks of Johnson County:

The samples selected for complete analysis are not of the pure phosphate minerals, but represent the highest grade rocks of the deposits. Thus there are present in the samples considerable quantities of gangue minerals and impurities such as silica, iron oxide, alumina, etc., which vary widely in the different samples and hinder the determination of the phosphate mineral and its composition.

A better idea of the composition of the mineral is obtained by disregarding the gangue material, and only considering those substances which vary in proportion to each other in the different samples: namely, CaO (lime), P_2O_5 (phosphorus pentoxide), F (fluorine), CO_2 (carbon dioxide), and H_2O (water). If these are added together, their sum considered as the pure mineral, and the percentage of each figured on this basis, then the results give the content of the phosphate mineral. Thus in sample 80 the CaO content becomes 54.4 per cent; P_2O_5, 34.5 per cent; F, 2.2 per cent; CO_2, 4.4 per cent; and H_2O, 4.6 per cent.

The H_2O content in this hypothetical mineral is high because it is the total water content and includes some hygroscopic moisture as well as the water of composition.

---

*See table of complete analyses at the end of this paper.

Digitized by Google

Judging from the analyses alone there may be some question as to whether the CO_2 should be included in this mineral, or placed with the required amount of lime to form calcite. A microscopic examination of the mineral failed to show calcite crystals, hence it is reasonable to suppose that the CO_2 belongs in the mineral, especially in consideration of the regularity of its occurrence in the analyses.

From the analyses it is impossible to classify the mineral except as a phosphorite, which is a mineral of composition varying from that of tricalcium phosphate, $Ca_3(PO_4)_2$, to fluor-apatite, (CaF) $Ca_4(PO_4)_3$, and often including CO_2. There is, however, some regularity in composition as is shown by the calculated content of the phosphatic portion of the other samples.

Hypothetical analyses of the phosphate mineral contained in the Johnson County phosphate rocks, calculated from the complete analyses, letting the sum of the actual percentage of CaO, P_2O_5, F, CO_2, and H_2O equal 100.

Sample	CaO	P_2O_5	F	CO_2	H_2O
79	38.1	47.9	2.7	5.6	5.7
80	54.4	34.5	2.2	4.4	4.6
82	45.9	34.8	1.3	1.0	3.1
84	51.9	37.2	1.9	4.4	4.7
85	56.1	38.1	1.7	3.2	1.9

Sample 82 is a different kind of rock and for that reason the substances composing it do not correspond in amount to those of the other samples. Sample 78 was not given above on account of its excess of moisture due to its clay content.

The following analyses of phosphorites, taken from Dana's Mineralogy, are given for comparison:

Analyses of phosphorites given by Dana.*

Locality	CaO	P_2O_5	F	Al_2O_3	Fe_2O_3	Mg O	insol.	CO_2	H_2O	Alk.
Amberg....	52.21	39.57	1.90	.....	0.9	0.09	1.96	2.78	.....	0.66
Staffel	45.79	34.48	3.45	1.08	6.42	0.16	4.83	1.51	2.45	1.00
" Staffelite	54.67	39.05	3.05	0.03	0.04	.....	.....	3.19	1.40	....

*Dana, *A System of Mineralogy*, Sixth edition, 1895, p. 766.

Digitized by Google

The theoretical composition of the Johnson County phosphate minerals also leads one to suspect that they may consist largely of a mixture, in varying proportions, of collophanite, $Ca_3(PO_4)_2.H_2O$, and dahllite, $2Ca_3(PO_4).CaCO_3.\frac{1}{2}H_2O$.

Analyses of collophanite and dahllite, taken from Dana are also given for comparison.

Analyses of collophanite† given by Dana.

Locality	CaO	P_2O_5	MgO	H_2O	CO_2
Sombrero	50.70	39.10	0.80	5.02	3.96
Mona	51.15	41.92	....	6.93	....

Analysis of dahllite given by Dana.*

CaO	P_2O_5	FeO	Na_2O	K_2O	H_2O	CO_2
53.00	38.44	0.79	0.89	0.11	1.37	6.29

TOPOGRAPHY AND PHYSIOGRAPHY.

Johnson County is not only surrounded by mountains, but it contains mountains within its borders. The lowest elevation within the county is a little less than 1900 feet above sea level, while the highest reached is nearly 5000 feet. On the eastern border lies Stone Mountain, while Holston and the southern part of Iron Mountain lie on the western boundary. The northern part of Iron Mountain, the whole of Doe, Forge, and Dry Run mountains, are within the county itself. Three of the main valleys head near Mountain City, making that town a central situation for a county seat. Roane Creek Valley lies to the south of it, the valley of the Laurel is located toward the north, while Doe Valley is in a southwestern direction from the town. The only other prominent valley in the county is Shady Valley, which lies between Holston and Iron mountains, and is drained by Beaverdam Creek, which flows northward into Virginia, as does the Laurel. All these valleys are, in their best parts, fairly level, extremely fertile, and well adapted to farming of almost any sort, some of the land being worth as

†Loc. cit., p. 808.
*Loc. cit., p. 866.

Digitized by Google

much as $150 per acre. They are not, however, extensive, and the lower end in every case terminates in a narrow gorge through which a stream escapes. The largest river in the county is the Watauga River, which cuts through Stone Mountain in the southern part and flows past the town of Butler.

The characteristic northeast-southwest trend of the mountains of East Tennessee is prominent in this region. The topography is effected by two principal factors: One is the structural relations of the rock beds, and the other is the pronounced

FIG. 5. Roane Creek Valley, looking southwest from the R. B. Brown place, near Maymead. In the foreground is a splendid cornfield. Stone Mountain lies to the left. (O. P. J.)

difference in their hardness and solubility. The general direction of the faults and the axes of the folds is northeast-southwest. The tendency of erosion to plane off the surface is modified by certain beds resisting the weathering and causing the formation of sharp ridges. Thus the mountains are largely composed of hard quartzitic sandstones and sandy shales, while the valleys are made up of more soluble and softer rocks, such as dolomitic limestones and calcareous shales. The mountain ridges follow anticlines (structural arches) and the edges of upturned rock beds, while the valleys follow synclines (structural troughs). The tops of the highest ridges expose the oldest rocks, and the bases of the valleys the youngest, showing that erosion has decapitated the mountains on account of the

Digitized by Google

steepness of their slopes, while in the valleys the rocks are leveled only locally. Each stream, in passing out of the mountain, cuts through a deep gorge in old hard quartzitic rocks. It was not necessary for the streams back of the gorges to do much work before they leveled the region to a common base, but below them it was necessary to cut through the hardest of the rocks before escaping from the mountainous region. For this reason in traveling to Mountain City, one passes through deep gorges with high, rugged bluffs, but finally comes out on flat, rich farm lands, surrounded by low foothills stretching

FIG. 6. Foothills, from the Baxter Gentry place, looking northeast toward the Cold Spring region. Note the buckwheat patch in the foreground. (O. P. J.)

off to high, steep mountains on all sides. It is in the foothill region between the valleys and mountains that the phosphate principally occurs.

In the process of erosion, pieces of sandstone have been carried from the older rocks of the mountains, and deposited over a large portion of the county. The insolubility of such bowlders and their resisting power has caused them to remain on the surface, even though some of the underlying rock beds have been removed from under them. Hills, composed only of the Shady limestone and Watauga shale, may be found in places perfectly isolated now from the sandstone mountains, but con-

Digitized by Google

taining a scattered mantle of these sandstone bowlders. In searching for phosphate, this mantle of loose sandrock materially interferes with one's work.

GEOLOGICAL FORMATIONS.

The descriptions of the geological formations in Johnson County, their structural relations, and the history of their formation, may be better understood if the accompanying map* and section are carefully studied. These things are important to know if a clear understanding of the phosphate problem is desired.

Granitic rocks.—The oldest of the rocks in this region are the granites (of probable *Archean* age), which are found mostly on the North Carolina side of the State line, but are also exposed in places in Tennessee. There is another strip of these granites occurring along a prominent fault line northwest of Mountain City at the base of Iron Mountain. These granitic rocks quite often react to the phosphate test. This fact is due probably to the presence of fine disseminated grains of *apatite*, a calcium phosphate mineral, which is quite common as an accessory mineral in granites, but hardly ever occurs segregated in large quantities in them. Cutting irregularly through these granites often occur other rocks, such as dikes of basalt. A dark bluish-green dike rock is quite common in places. This also reacts to the field test for phosphate, and although it has never been found to contain more than 4 per cent lime phosphate, it created much excitement for a while in Johnson County. It is interesting to know, however, that these older rocks often contain phosphatic material, for more than likely they are the source of the phosphate found in the sedimentary beds of later origin.

The Unicoi formation and amygdaloidal basalt.—Above the old granites lie sedimentary beds of *Cambrian*† age. The first

*See map at beginning of this paper.

†All the sedimentary rocks in Johnson County are of *Cambrian* age. The Cambrian beds are at the base of the distinctively sedimentaries in Tennessee, consequently are very old. Since this is such an old formation it can readily be seen that a great many changes in the rocks could have taken place, both locally and generally, since they were deposited.

Digitized by Google

of these to be deposited on top of the granites were beds of conglomerate, sandstone, and slaty shale. The materials composing these beds are simply water-worn fragments of the old granitic series of rocks. For that reason a little phosphatic material may be found in some of these rocks, such as the sandstones, which not only contain quartz grains, but also water-worn fragments of feldspar, mica, and other minerals, such as apatite, all of which occur in the granites. This formation, or rather about 2000 feet of it, is classified by the United State Geological Survey as the *Unicoi formation.* Near the middle of it lies a bed of dark-blue to bluish-green, and in places, black rock, which is very tough and hard, exposed all along the steep mountain wall of Iron Mountain. This bed of rock reaches a thickness of 150 feet. It consists of a fine matrix with larger crystal grains which are very often more soluble than the rest of the rock. The weathering effect is to cause little holes to be dissolved out of the rock, each about a a quarter of an inch in diameter. These little crystals are of no special economic value, but occasionally they are of calcite, in which case the layman testing the rock with acid, will find a strong reaction for lime, leading him to believe the rock to be a limestone, which it distinctly is not. Instead it is an *amygdaloidal basalt*—a kind of lava — which was pored out over the surface of the newly deposited sedimentary beds and was covered later by sand and mud which now constitute the sandstone and shale that lie above it. It is an old lava sheet interbedded in sedimentary rocks. It has the same appearance as the bluish dike rocks in the granites. In fact, it may be that these dikes represent the course of the flow, as the material was expelled from within the earth through fissures, out upon the surface as a lava sheet. The interesting fact in this connection is that this blue bed of rock reacts to the field test for phosphate, and excited the people who were searching for phosphate rock, although chemical analyses since made show it to contain not much over 2 per cent phosphate of lime.

The Hampton shale.—The Hampton shale as mapped by the United States Geological Survey, consists of about 700 feet of bluish-gray, sandy shales. It is somewhat similar to and lies above the Unicoi formation.

Digitized by Google

The Erwin quartzite.—The Erwin quartzite is one of the most resistant of the hard sandstone formations in the county. The rocks consist of about 600 feet (according to the Federal Survey) of white sandstone or quartzite, and form many of the sharp crests of the mountains, such as that of Doe Mountain. Large fragments from the ledges of this formation often strew the sides of the mountains and roll down into the valleys.

The Shady limestone.—The old, harder, more siliceous rocks form in themselves a distinctly different series from the younger formations above them. Geologically, above the Erwin quartzite lies the Shady limestone, which, in Johnson County, flanks the sides of the mountains, often forming the foothill region. This formation consists of about 800 feet of massive magnesian limestones or dolomites with a few interbedded shales. The rocks, seamed with white calcite and dolomite, are usually gray or bluish-gray, but in places some layers are white, blue, pink, and mottled. The weathered surface of the rock is often dark-gray or black. Many of the beds are more or less siliceous, containing nodules of chert and chalcedony, most of them containing at least a trace of phosphatic material. In places chert deposits are quite extensive. Decomposition and disintegration in this formation are much more rapid than in any other of the county. In places where the lime has been dissolved out, red and yellow clay, filled with chert lumps, is left as residual material. In these residual accumulations often occur iron and manganese deposits and, in certain regions, deposits of phosphate. In the upper part of the beds of the Shady limestone, calcareous shales occur which grade over into the red shales of the Watauga formation. In many places the shales and magnesian limestones of this horizon are more apt to be phosphatic than rocks of other horizons, and it is generally in these beds that the concentrated accumulations of phosphate rock occur.

The Watauga shale.—The Watauga shale formation, into which the Shady limestone grades from below, consists for the most part of shales, interbedded with dolomitic limestones and sandstones, of red, blue, green, yellow, and variegated colors. The dolomitic limestones are quite similiar in appearance to those of the Shady limestone, but frequently they are more sili-

Digitized by Google

ceous, and rarely exceed 10 feet in thickness. These dolomitic limestones are also slightly phosphatic. The whole formation has been approximated by the United States Geological Survey as being about 1000 to 1100 feet thick. In the more calcareous strata of the lower beds of the formation, chert masses are common, which often contain inclosures of limonite and manganese. Here also are found in places phosphatic masses associated with chert. Decomposition of the Watauga shale is peculiar in certain localities. In places the formation consists of a fine, sandy shale, which weathers to a great depth, forming a mass of loose, fluffy material which has the appearance and nature of the material known commercially as "tripoli" or "silica." In these masses are also found deposits of iron and manganese—a good example being "Yellow Hill," in the iron mines just east of Shouns.

STRUCTURE OF THE ROCKS.

The structure or lay of the rock beds in Johnson County is very complicated. It is difficult, in places, to determine with any degree of accuracy the detail of local structure on account of the soil covering, the deep disintegration of some of the beds, and the wash from the mountains.

The general strike of the rocks is northeast-southwest. The main valleys follow synclines which contain in themselves many minor folds, while the principal ridges follow anticlines as does Doe Mountain, and the upturned edges of faulted rocks, as does Iron Mountain. The three principal synclinal valleys which are of interest here are the Roane and Doe, which lie on either side of Doe Mountain, and which apparantly join at Mountain City and form the third, the Laurel Valley. Local folds and crumpling in the beds are extremely common, but the effect of such disturbance depends largely on the kind of rock present. For instance, the Erwin quartzite resists compression effectively; the Shady limestone breaks readily; while the Watauga shale wrinkles in many shapes. Even hand specimens of the Watauga shale may be found highly twisted. Several prominent fault lines follow the strike of the beds and along these lines the rocks are often displaced enormously. Most of them are thrust faults showing compression in the

Digitized by Google

rocks from southeast-northwest directions. A great fault is present at the foot of Iron Mountain, where, in places, the oldest rocks (the granites) have been brought side by side with the youngest of the formations (Watauga shale) showing a displacement which is conservatively estimated as more than 4500 feet, judging from the columnar section given by Mr. Keith in the Cranberry folio.* The top of Iron Mountain contains rocks which were formerly at the same level as certain rocks over 1000 feet below the Watauga shale, which now lies at the base of the mountain 1500 feet below its summit.

All this folding, faulting, and compression of the rocks have caused them in places to contain many fractures and cracks. Into these cracks water solutions have passed, dissolved out, and deposited various minerals. Particles and combinations of minerals of iron, manganese, silica, phosphate, magnesium, and calcium carbonate were originally disseminated through the rock beds, and the percolating waters acted upon them, dissolving some of them and precipitating others. Certain of the minerals were more soluble than others; and certain ones became more soluble, or precipitated in the presence of others, during the change of pressure and temperature, or under some other peculiar conditions. The final result of the disturbance in the rocks and the circulation of the underground waters was that the fractured rocks were cemented together as they were fractured.

It is principally in the Shady limestone, in the regions where this formation is closely connected with structural disturbances, that interesting deposits of minerals may be found. The bed rocks of this formation are generally full of seams and veins of calcite and quartz, forming a cobweb effect in the rock. Often the dolomitic limestones are brecciated—that is, broken into many small angular fragments and cemented by some mineral. Usually this mineral is calcite or dolomite. In places it may be a form of silica, some oxide of iron or manganese, or, as in deposits considered here, a phosphatic material.

Thus the stucture of the rocks, both in general and in particular, should be studied in order to determine the occurrence of the deposits as well as their nature and origin.

---

*U. S. Geol. Surv. folio, 90.

Digitized by Google

GEOLOGICAL HISTORY.

Before any sedimentary rocks, such as shales, limestones, sandstones, and conglomerates were deposited in this area, there existed to the east a continent of older rocks, including the granites, classed by geologists as of *Archean* age. Erosion on this continent washed gravel and other sediments derived from these older rocks into the sea and distributed them in layers, or stratified beds, on the old sea bottom. The rocks thus deposited are of *Cambrian* age. The first of these gravels is represented by the basal feldspathic conglomerates of the Unicoi formation, well exposed along the foot of Iron Mountain. As the sea encroached upon the land, sands and finer silts were deposited, for they were then being washed farther out in the sea. These are now found as sandstones and shales. During this time the mass of lava above described was laid out over the bed of sands and formed what we now term the bluish-green *amygdaloidal basalt* of Iron Mountain. More sands and silts were then deposited, washed from the same old land mass, and from newly formed land, made by lava flows and by uplifted areas of deposited sediments. Later certain parts of the sea were clear and little sediment was deposited. This gave rise to conditions which caused the accumulation of calcareous beds, which later changed, by age and through peculiar underground conditions to what is now known as the Shady limestone. Continuation of finer deposition of both calcareous matter and silt formed the Watauga shale.

Mountain-making forces caused these rocks to become squeezed, thrown into folds, broken and twisted into many shapes.

For a long while these rock beds have been above the sea. They have been eroded to a very great extent. The soft rocks have been worn off; the hard rocks resisted and stood out in relief. Weathering and underground solutions have caused many changes in the surface and peculiar local deposition of minerals.

Digitized by Google

LOCATION AND NATURE OF THE PHOSPHATE ROCKS.*

Prospecting for phosphate rock in Johnson County has been carried out on several hills 2 or 3 miles north of Mountain City, near Cold Spring, and in the region of Maymead, about 4 miles south of the city. Some of the phosphate at both places has the same general appearance; but in the Cold Spring region most of it is soft, earthy, and decomposed, while near Maymead it is in places quite hard, its texture being distinct. Many small deposits of this material occur over the county.

The phosphate localities may be described in three groups: (1) The one north of Mountain City; (2) The one in Roane Creek Valley; and (3), The one in Doe Valley. They are here taken up in the same order as the commercial analyses are given in the tables. Other rocks (dolomitic limestones, siliceous dolomitic limestones, and calcareous shales, and other miscellaneous phosphate-bearing rocks) and their localities will also be described, since they have more or less bearing on the problem of the phosphate.

DEPOSITS NORTH OF MOUNTAIN CITY.

Baxter Gentry place.—Two and one-half miles northwest of Mountain City, on a round hill at the foot of Iron Mountain, on the property of Baxter Gentry, lies the phosphate rock first discovered in Johnson County. The deposit is residual and occurs, geologically, probably in the lower part of the Watauga calcareous shale, although no exposures of the original bed rocks are present, definitely to determine this fact. It is located a few hundred yards east of the Iron Mountain fault, which has a displacement of about 4500 feet, and whose displacement has caused the granites to come into contact with the Watauga shale. The disturbance accompanying this faulting is probably the cause of the general brecciation of the rocks containing the deposit.

In May, 1915, the State Geologist collected a specimen (A) from the Baxter Gentry place. The rock was taken from the surface outcrop by means of a pick. It shows a higher per-

*The numbers of the samples in the following descriptions refer to the numbers of the analyses in the tables.

Digitized by Google

centage of calcium phosphate than the other samples collected by the writer in the locality.

The first real prospecting for phosphate in the county was begun in July on the Baxter Gentry place. Trenches were dug across the hill uncovering the rock. The largest of these trenches was first dug 6 feet deep and 50 feet long. Work was then stopped, but later resumed. In this later work the large trench was sunk 15 feet deep, clear through the top of the hill,

FIG. 7. Phosphate prospect trench through hill on Baxter Gentry place, looking northwest. The windlass is placed above a 45-foot shaft. Phosphate here will run from 30 per cent to 50 or 60 per cent lime phosphate. The dirt averages nearly 10 per cent. (A. H. P.)

its length being 150 feet. Then a shaft was sunk in the center of the trench, which reached a depth from the surface of 45 feet. Heavy rains immediately followed the digging, which caused the shaft to cave in, and work was not again resumed. Other pits of less consequence were also dug. No solid bed rock was encountered and all the material proved to be residual. The original rock was probably limestone or calcareous shale, although it is impossible to determine this fact exactly. Brecciation is predominant, but somewhat obscured by disintegration. The material consists of phosphatic chert or chert coated with lime phosphate, occurring in chunks or "donnicks", varying in size from small fragments to pieces several feet in diameter, of clay and phosphate rock, all having a somewhat yel-

Digitized by Google

lowish appearance. Chalcedony is present in small fragments. Iron and manganese stains are prominent. Most of the rocks and dirt of the hill indicate phosphate if the field test is applied. Some of the rock fragments contain a large amount of phosphorus, while others contain almost none. For that reason, it is difficult and perplexing to sample the material. For instance, the sample taken by the State Geologist was from the surface of a "donnick", whose center proved later to be composed mostly of chert.

Sample 16 was taken as a general representative of the prospect trench after it had been dug about 6 feet deep.

Sample 17 represents the general contents of a "donnick", or large chunk of phosphate rock occurring near the surface which, from outside appearance, seemed to be all phosphate, but internally was largely silica.

Sample 18 shows the general phosphatic character of the dirt removed down to the depth of 6 feet.

Sample 83 was taken from the bottom of the 45-foot shaft. The material consisted of earthy yellowish-brown rock, containing some thin whitish coatings.

Sample 84 (see table of complete analyses) was taken from the depth of about 10 feet. The material consisted of yellowish, earthy, fragmentary, soft rock with a white coating of acicular crystals (the appearance of mold) over each fragment. This white coating, according to Dr. A. F. Rogers, of Stanford University, is a zeolite, a hydrous calcium silicate.

Sample 90 was taken at a depth of 10 or 15 feet from a clayey yellowish material in the northern end of the prospect trench.

Along the same general strike of the rocks in this region, a little limestone is present in a stream bed just northeast of the Baxter Gentry place. In the same northeast line on Clint Slimp's place there is a little phosphatic material on the side of the hill, intermixed with chert fragments. Beyond this, on adjoining land owned by E. E. Butler, there is a small outcrop of brecciated impure limestone, slightly phosphatic, but having much the same appearance as the weathered residual material of the Baxter Gentry locality.

J. S. Jenkins place.—Three miles northwest of Mountain City, just west of Cold Spring, and 1½ miles northeast of the

Digitized by Google

Baxter Gentry place, are a number of deposits of phosphate, the principal ones being those on the J. S. Jenkins land. These deposits occur in geologic and topographic positions similar to those of the Baxter Gentry place. The material is residual, and occurs probably in the upper part of the Shady limestone or the lower part of the Watauga shale. At Cold Spring, the Shady limestone is the surface rock, having been there raised in a structural dome and dissected by small streams.

The prospecting was done first by uncovering the phosphate and then by sinking pits. Two hills were examined, one above the orchard and the other to the east, adjoining the Hendrix place. The material found in these pits proved to be much like that of the Baxter Gentry place. It consists of phosphate rock, clay, shale, and chert mixed more or less together and brecciated, with prominent stains of iron and manganese. Many colors are present, such as red, brown, yellow, black and white, but in general the material is a red, brownish-yellow. In some of the pits, the bedding can be discerned, whose dip is almost vertical and whose strike is northeast-southwest. It appears as if these rocks formed the flanking sides of the structural dome, whose center is near Cold Spring, where the Shady limestone is exposed.

Sample 28 was taken from a 15-foot prospect pit near the top of the hill lying just east of the orchard, and is typical of the phosphate rock present in the pit. In this pit all the material is quite disintegrated, although bedding planes are discernible. The phosphate rock has a tendency to lie between beds of clayey material, but is not consistent in doing so, for particles of phosphate are present, scattered throughout the whole mass. The phosphate consists of yellowish-brown, earthy rock, containing specks of manganese minerals. It all contains a large quantity of siliceous material and is usually more or less intermixed with chert.

Sample 29 was taken from a prospect pit on the same hill, farther down the slope. The material consisted mainly of a porous sort of yellowish-red clay which reacted to the field test for phosphate. Analysis shows, however, that it is practically barren of phosphorus.

Digitized by Google

Sample 30 was taken from the surface material, before prospecting began, in the cornfield near the top of the hill adjoining the Hendrix land. This locality is within 200 yards of a limestone quarry and kiln where the rocks lie practically horizontal, being situated at the top of the Cold Spring structural dome. The surface material, where the sample was collected, consisted of rather soft, brecciated, whitish phosphate rock, containing red, brown, black, and yellow streaks. It reacted readily to the field test.

FIG. 8. Phosphate prospects on the J. S. Jenkins place, near Cold Spring, looking east. Brecciated phosphate rock thrown out here (sample 30) ran nearly 50 per cent lime phosphate. (O. P. J.)

Sample 38 was taken at this same locality after a prospect pit 14 feet deep was dug. The sample represents a fair average of the phosphate rock present in the pit. The rock from which sample 30 was taken did not exist at a greater depth than a few feet. The material under it proved to be a softer, clay-like substance of various colors and having no very distinct bedding planes. It may, however, be that these rocks lie on the edge of the Cold Spring structural dome at its point of turning, and for that reason they are somewhat disturbed as well as brecciated. Further digging in this locality disclosed a quantity of peculiarly mixed, varicolored clay, phosphate fragments, and residual material of many kinds, which proved to

Digitized by Google

be unstable in vertical faces, for the cut finally caved in on all sides.

Adjoining the property of J. S. Jenkins on the east along the top of the hill on the Hendrix place, there is a little residual phosphate. Some of this phosphate rock occurs above the limestone quarry, which is on the hillside on Jenkins' land. An interesting relation exists here between the phosphate rock and the underlying beds. In this quarry the principal rocks are massive, hard, compact, high-grade magnesian limestones, overlain directly by about 4 feet of hard, black, carbonaceous shale,

FIG. 9. Same prospect as shown in Fig. 8, looking northwest. At a depth of 10 feet the phosphate rock (sample 38) ran a little over 32 per cent lime phosphate. (O. P. J.)

followed by grayish-green, sandy shale. The black shale reacted to the field test for phosphate, but its content of phosphorus is small, as indicated by sample 36. Above these shales the bed rocks are not exposed, but on top of the hill, fragments of phosphate rock, some cherty pieces, and weathered fragments of magnesian limestone occur. No doubt the topmost beds, which are covered with residual soil, and these rock fragments are limestones or dolomites, which contain some phosphatic material. This same relation exists on the property adjoining the Jenkins place on the north, on the hill which lies between the road on the east and the site of a former branch

Digitized by Google

railway which passed Cold Spring. Also this same geological relation is more fully exposed along the road between Jim Newt Wills' house and Silver Lake, which locality is described at length elsewhere. This geological relation of the rocks should serve as a guide to the prospector.

Between the dirt road and the main railroad near Cold Spring station, decomposed phosphatic material exists in the hillside, in much the same manner as that already described nearby. The rocks dip toward the southeast, and it is here that the opposite side of the Cold Spring structural dome is encountered: *i. e.*, opposite from the prospect on the Jenkins property. North of Cold Spring station, in a railroad cut, is a very small deposit of brownish, earthy phosphatic residual material, indistinctly bedded.

FIG. 10. Prospect pits in phosphate rock on A. H. Fritts' place, 2 miles north of Mountain City, looking east. Phosphate rock, running over 54 per cent lime phosphate occurs here. (O. P. J.)

A. H. Fritts place.—East of Cold Spring station, on top of a hill overlooking the road which leads to Fuller station, on A. H. Fritts' land, more prospecting was done. The geological relation here is difficult to determine. The formation present is probably the lower portion of the Watauga shale. The nearest rocks exposed are shales that stand on end, striking northeast-southwest. The deposit is residual, the bedding being almost

Digitized by Google

obliterated by weathering. Prospecting was done by means of digging several trenches and pits, not over 5 feet in depth. The material removed consisted of weathered, soft, light-weight brecciated phosphate, mixed with clay, chert, and chalcedony, filled with stains of iron and manganese minerals. Although most of the phosphate is siliceous, it could be easily pulverized, for it is already in a state which would require only a little breaking up to reduce it to a state of powder. In plowing the field, this material is more or less distributed over the land on either side of the deposit, and apparently with a certain beneficial effect.

Sample 67 was a picked sample. That is, it was taken with the intention of avoiding the main bodies of siliceous matter, but to represent the general nature of the better grade of phosphate in the prospect. The material was a whitish-gray, fairly soft rock.

Newt Jenkins place.—About one mile northeast of Cold Spring station, on the hillside east of the road, one-half mile south of Fuller, occurs a deposit of phosphate on land belonging to Newt Jenkins. No prospecting had been done when the place was examined by the writer, but the indications were quite similiar to those of the J. S. Jenkins prospect in the cornfield. The phosphate rock consists of soft, brecciated, white and brownish-yellow, porous rock, containing numerous particles of manganese and iron minerals. The effect, if any, of this residual phosphate on the corn crop of the field was beneficial. This material is limited to a very small area on the hillside, the surrounding residual rocks being largely chert fragments. Although no bed rock is exposed nearby, it is quite evident from the surrounding geological features that this deposit lies on or very near the contact between the Shady limestone and the Watauga shale.

Sample 39 was taken from residual phosphate rock occurring in fragments or chunks on the surface of the ground, upturned by the plow. The material consisted of brownish-white brecciated rocks. In sampling, the chert was avoided, and a fair representative of the better grade of phosphate rock was collected.

Digitized by Google

Scott Fritts place.—A part of a day's work in prospecting was done on Scott Fritts' land, one and a half miles north of Cold Spring, a half mile west of the point where the dirt road crosses the railroad. The prospect is situated near the top of a low ridge, three-quarters of a mile east of the granite rocks and the Iron Mountain fault. Three prospect pits were sunk, each about 5 feet deep. The material exposed in the pits was a light-yellow, porous, shaly, light-weight, residual rock, containing black manganese specks and some whitish matter. It reacted slightly to the field test for phosphate. A large quantity of siliceous rocks and cherts are present in this locality. Although this place is on the same northeast-southwest line of the Baxter Gentry, and J. S. Jenkins places, phosphate rock is not very strongly indicated.

Sam Butler place.—About a mile northeast of Mountain City on top of certain foothills to the east of the point where the main road crosses the creek, a few hundred feet above the road, occurs a deposit of phosphatic material on Sam Butler's place. A few shallow pits were dug, but they hardly went below the surface soil. No rock in place occurs on these hills, but from a study of the surrounding geological conditions, it appears that the scattered residual phosphatic rocks that occur on the hillsides are not far from the contact of the Shady limestone and Watauga shale, which the United States Geological Survey at this point maps as a fault contact. The residual float phosphate rocks consist of porous, yellowish, siliceous material imbedded in brown clay, slightly streaked in places with white, the whole appearing brecciated, although the texture is practically obliterated through weathering.

Sample 8 was taken from a prospect pit 2 feet deep, at the head of a hollow on the side of the hill. The material is surface, weathered phosphate rock, taken as a fair representative of the phosphate rock of this prospect.

Sample 2 was taken as a fair representative of a prospect pit 2 feet deep, dug on top of the same hill. The material is a weathered phosphatic clay shale.

Ham Snider place.—A little phosphate occurs on Ham Snider's place on the ridge west of Sam Butler's, 1 mile north of Mountain City. It was turned up during the plowing of the

Digitized by Google

field. The material consists of a soft, earthy, residual, yellowish, somewhat siliceous rock. Although no bed rocks are exposed here, it appears through study of the surrounding exposures that this lies near the contact of the Watauga shale and Shady limestone. In fact one-quarter mile northward, there is a small quarry and kiln in a limestone outcrop.

Sample 42 was collected from the surface residual phosphate rock from this deposit on Ham Snider's place.

Andrew Johnson place.—About 2½ miles northeast of Mountain City on Andrew Johnson's place, situated on the steep hillside, 100 feet above and west of the point in the road where it leaves Furnace Creek and starts up the hill, there is an interesting deposit of phosphate rock. Although bed rock is not well exposed on the hill, it appears that the deposit is resting on or near the contact of the Watauga shale and Shady limestone. The phosphate appears to be in place as a sort of residual pocket, with much the same appearance as that of the other ones already described, but less altered by disintegration, and consequently much harder.

Sample 55 consisted of yellowish, brecciated rock, taken from the outcrop, lying close to a poor exposure of reddish shale.

Sample 71 was from a brownish, brecciated rock, full of seams of iron and manganese.

Sample 72 was taken from the outcrop of a whitish hard rock, having much the same appearance as that of the white flint in limestone.

About a mile north of this last phosphate locality, in a field on the side of a hill lying west of the home of Norman Wills, a fragment of phosphate rock was found, similiar in appearance to those of the phosphate in the cornfield on the J. S. Jenkins property, but the deposit from which it came was not located definitely.

Baxter Wills place.—Four and a half miles north of Mountain City and one mile west of Wills station on a low knoll north of a private road near a large barn, the property of Baxter G. Wills, there is a little residual phosphatic material scattered over the surface of the ground. It is associated with fragments

Digitized by Google

of chert, sandstone, and soil. On account of lack of exposure, it is difficult to determine the relation of this deposit to the geological formations, but it appears that the underlying beds are probably those of the Watauga shale. The geological and geographical position of this deposit is similiar to those of the J. S. Jenkins and Baxter Gentry properties, but its extent is probably less.

Sample 9 was taken from surface material near the barn of Baxter G. Wills.

Silver Lake region.—Phosphatic material occurs in the region of Silver Lake, which lies at the head of Laurel Valley, 5 miles north of Mountain City. The Shady limestone and Watauga shale are in contact along the northeast-southwest line in this locality, and residual phosphate is found near this line. Between the point where the main road crosses Dyestone Branch near Jim Newt Wills' house and Silver Lake, there is a more or less continuous exposure of the rocks in the road. These rocks stand at an angle of 45°, dipping towards the northwest. Starting with the lowest of these beds near Jim Newt Wills' house and traveling towards Silver Lake, one may find the following rocks: Massive, hard, blue limestones, or dolomite, containing many white calcite stringers, followed by a 10-foot bed of shale, the basal portion being black; above this lie thin, even-bedded, gray limestones, shaly limestone, white, pink, and gray calcareous shales, and hard limestone, all of which are slightly phosphatic. These are overlain by red shales of the typical Watauga formation. The phosphate rock is of residual nature and is associated with the interbedded shales and limestones of slightly phosphatic content.

The black shale present in this section is no doubt the same bed as that occurring in the quarry on J. S. Jenkins' place near Cold Spring (sample 12). It reacted to the field test for phosphate, and the adjoining beds did also. The geological horizon for phosphate at this place is, therefore, the same as that of the J. S. Jenkins place.

Sample 73 was picked up from the surface as a representative of the highest grade residual phosphate rock which occurs scattered over the side of the hill, on Baxter G. Wills' place, east of the junction of the Laurel road and the road from Wills

Digitized by Google

station. The material occurred in the transitional beds of the Shady limestone and Watauga shale as the weathered product of shaly limestones.

Sample 75 was also picked from residual float material from two low knolls just north of this last locality and on the opposite side of the road, east of Silver Lake, on land owned by Mrs. Sutherland and by Nat T. Wills. This material is evidently the weathered product of calcareous shales which originally contained some phosphorus.

Phosphate rock of similar character and occurrence have been found north of Silver Lake on land belonging to Nat T. Wills and on A. F. Mock's property. Conditions are favorable for the discovery of phosphate deposits farther toward the north, but none have yet been reported. Limestones and shales of phosphatic character occur towards the northeast, even as far as Taylors Valley, Virginia.

E. E. Butler place.—Two and a half miles northwest of Mountain City, about one-half mile east of the Baxter Gentry place on top of a "slate" ridge, on Senator E. E. Butler's land, which lies on the south side of the road, connecting Cold Spring with Cress Creek, there is an entirely different kind of phosphate from any so far found in the county. The backbone of the ridge is cherty shale standing almost vertical, dipping towards the northwest, with a definite northeast-southwest strike. A small number of pieces of very hard phosphate rock, weathered grayish, none of which are much larger than a man's fist, occur in a certain very limited locality about the roots of a tree. No surface exposure of this rock occurs in place, and since it has not been prospected, it is impossible to determine the exact position of the phosphate in relation to the other rocks, since soil and leaves cover the outcrop. Cherty shale is exposed, however, on all sides, and the phosphate, excepting the float found on the hillsides below, can not be traced farther than a limited area of a few square yards.

Sample B was taken by the State Geologist.

Sample 82 (see table of complete analysis) represents the general character of the phosphate which occurs on the surface and in the soil. The material before weathering, is a dark-blue, almost black, dense, hard and tough rock, containing some

Digitized by Google

shining siliceous crystalline material. Its weathered surface is light-gray, in great contrast to an unweathered fractured surface. The siliceous material stands out in rough relief on this weathered surface. The dark coloring is due to organic matter.

ROANE CREEK VALLEY AREA.

The phosphate area of Roane Creek Valley lies principally between Shouns and Neva in the foothills which lie on the west side of the valley, along the edge of the Doe Mountain range. The nearness of the phosphate deposits to the broad-guage railroad makes them especially attractive to prospectors.

Phosphate rock in Roane Creek Valley was found about one mile northeast of Maymead, near the road on R. B. Brown's place. Prospecting was started and several trenches were dug and some pits opened. The prospectors then moved to another deposit which seemed more promising, on land owned by Charley Brown, which joins the other property on the north. Although still better appearing deposits of phosphate rock were discovered close to Maymead on another part of R. B. Brown's place and on J. S. Vaught's land, adjoining that of the former on the northwest, prospecting was discontinued. Better light would be thrown on the problem if these latter deposits were opened up and their character displayed.

R. B. Brown place.—Some years ago iron mining was carried on by the Virginia Iron, Coal, and Coke Company, a few miles north of Maymead on the side of Doe Mountain. A narrow-guage track was laid from Maymead to the mines, passing through R. B. Brown's place, and running up the little valley which lies between that land and Charley Brown's place.

It was along this railroad, not far from the main Mountain City road, that prospecting was carried on. The exposures for about a mile along the lower end of the railroad, which runs along the edge of a hill, disclosed many interesting facts. The rocks of this area are mapped by the United States Geological Survey as the Shady limestone. The whole region seems to have been badly disturbed, and the ridge seems to contain an overturned anticline. Local faulting in places breaks the general strike of the rocks and, of course, the phosphate horizon. Starting from Maymead and going northeastward along the

Digitized by Google

track nearly parallel with the strike of the beds, one finds the following rocks: Shaly limestones, dipping nearly vertical; soil covered area; massive limestone or dolomite, quite brecciated and somewhat phosphatic; some cherty brecciated phosphatic limestone; soil covered area; brecciated chert with phosphate rock intermixed with it, standing in bluffs 75 feet high; cherty residual material continuing to a trestle on the north side of which a prospect pit has been sunk to a depth of 45 feet. Beyond the trestle along the railroad other prospects are found, some of which are trenches, and others, merely uncovering of the phosphate. At the end of the hill, the railroad turns and runs northwest, and here are exposed beds of limestones, shales, and sandy rocks, which are more or less phosphatic; beyond this the rocks have been uncovered and yellowish, brecciated, somewhat cherty rocks, filled with white phosphate incrustations, are disclosed.

The whole hill lies with the strike of the rocks, which are magnesian limestones and shales. The deposits of phosphate rock are residual and lie irregularly on top of the disintegrated edges of the beds. The brecciated chert and phosphate, occurring not far from Maymead, are found farther up the hill to grade into the original dolomitic limestones. Thus pieces and patches of high grade phosphate, phosphatic dolomite, and chert, all more or less brecciated, occur in this small area. The brecciation accompanied the complex disturbances of the rocks. The chert would make most excellent road material, being fractured and full of iron cementing matter. The phosphate might be of local value as pulverized raw rock for fertilizer, although a great quantity can not be expected on account of its pockety occurrence.

Sample 12 was taken from the surface exposure near the trestle of the railroad, to represent the general character of the phosphate rock there. Most of this rock is mixed with chert. It is yellowish with some white streaks, and is brecciated and somewhat weathered.

Sample 62 was taken half way down a 45-foot prospect pit near the trestle. It consisted of yellowish-brown earthy phosphate rock, occurring as fragments and irregular masses and seams, imbedded in cherty clay.

Digitized by Google

Sample 61 was taken at the bottom of this same 45-foot pit. The material was brownish-yellow, reacting well to the phosphate test. In this pit no regular bedding can be discerned. The cut goes through clays, lumps of yellowish-white phosphate rocks, containing iron and manganese minerals and loose siliceous clayey material. Towards the bottom of the pit fragments of siliceous, dolomitic limestone, of slightly phosphatic nature, occur in irregular ledges, showing that the original rock was in part, at least, limestone or dolomite. The whole mass is highly fractured and brecciated, the phosphate rock occurring in seams in the crevices, and also intermixed with the whole mass.

Sample 63 was taken from surface residual phosphate rock occurring on top of the hill above the iron-ore washer. This is about the best phosphate locality on this property. The material consists of hard, yellowish, brecciated rock, containing black manganese specks and some whitish minerals of phosphate. Some of the rock is laminated or banded in structure. This rock is in close association with magnesian limestones, shales and cherts. It occurs as a residual pocket. No prospecting has yet been done here.

Charley Brown place.—Northeast of the property last described is situated the phosphate deposits on Charley Brown's land. This deposit occurs in the woods adjoining an open field near the top of a foothill, several hundred feet above the valley. The surface outcrop consists of a hard, brecciated rock, no doubt originally a magnesian limestone. It has the general appearance of white and brown chert. Besides the chert, the rock contains chalcedony, but a large part of it is phosphate.

Prospecting was started here and disclosed interesting facts. If these rocks had been acted upon greatly by weathering, their appearance would probably have been somewhat like that of the deposit on the Baxter Gentry place. But they are not badly weathered, and are very hard, showing distinct brecciation and distinct coloring of the different fragments composing the breccia. A white, bony, cementing material, apparently phosphate mineral itself, fills cavities in stalactitic form. Black manganese minerals of crystalline form occur in the breccia as vein filling material. The phosphate rock seems to be of

Digitized by Google

various colors—brown, white, reddish, and yellowish. It is harder than limestone, but can readily be scratched with the knife, which distinguishes it from the chert and chalcedony which it closely resembles, and with which it is associated.

The prospect pit was made in the form of a rough trench, dug in a southeast-northwest direction about 60 feet long, 5 feet wide, and, in one place, reaching the depth of 10 feet, cutting across the deposit. Bed rock was not reached. The material encountered was massive, brecciated, varicolored phosphate rock, with stringers of manganite and other manganese minerals. Chalcedony also was present, as well as light-yellow, porous, phosphatic clay, the whole appearing to have originated from beds of limestone and shale, although no dip was perceptible.

Sample 65 was taken as a representative of the surface exposure.

Sample 76 was taken as a general sample of the phosphate rock removed from the prospect pit. This shows the character of the material as dug directly from the hill.

Sample 78 (see table of complete analyses) was a picked sample of the hard, bony white phosphate rock which occurred throughout the prospect pit.

Sample 80 (see table of complete analyses) represents the brownish-red type of phosphate.

Sample 79 (see table of complete analyses) represents the brownish-black type, which apparently contained a large amount of silicia and manganese.

Sample 77 was taken as a general representative of the dirt thrown out of the prospect pit. It was a yellowish material full of small fragments of phosphate.

Sample I was taken by Dr. J. H. Pratt, of Tampa, Florida, and analyzed in the J. H. Pratt Laboratory. The specimen was composed largely of the white variety of phosphate, with some of the reddish-brown mixed with it. It was a piece which probably represents the highest grade of rock in the deposit.

Between Shouns and the Charley Brown place, along the foothills west of the main road, occur small scattering deposits of phosphatic material. One is very near the road, opposite the "Station One Mile" sign, south of Shouns.

Digitized by Google

J. S. Vaught place.—A third of a mile down the railroad from the station of Maymead is the postoffice of Vaughtsville. West of this place, and of Maymead, is the property of J. S. Vaught, which adjoins that of R. B. Brown on the south. On this land, along the sides of the foothills, lie residual deposits of phosphate rock occurring in a similar manner to those on the adjoining Brown land. Most of the phosphate rock is light-yellow, hard, not yet disintegrated, and brecciated, with the cavities filled or partially filled by white calcium phosphate minerals in stalactitic forms. The rock itself contains some chert, quartz, and chalcedony. Some pockets here may prove to be of value when prospecting has been done.

Sample 60 was taken from surface residual phosphate rock found on the hill back of the iron washer on the Vaught place. The material was yellowish, hard and specked with black manganese minerals.

Sample 87 was taken from the surface exposure of phosphate rock, on the side of the hill back of the iron-ore washer, 150 feet above the railroad station of Maymead. The material consisted largely of yellowish, brecciated rock.

Sample 89 was taken from the surface float rock occurring on the side of the hill in front of the church at Vaughtsville. The sample was of a hard, light-yellow rock, of peculiar laminated or banded form, with the appearance of even-bedded calcareous shale. It was brecciated and had a filling of white phosphate incrustations.

W. G. Nave place.—Southwest of these deposits near Maymead, lying in the same range of foothills, there is some residual phosphate. That on the property of W. G. Nave, situated about one-fourth of a mile northeast of Neva, is of special importance. On the side of the hill some float material occurs, but in the deep hollow between that property and the adjoining land on the south, phosphate rock occurs in place. The main body of the exposures consists of the Shady limestone. The exposure of phosphate is composed of hard, yellowish, brecciated rock with the appearance of chert. Its cracks and crevices are filled with white botryoidal incrustations which are about a millimeter thick and consist of crystalline phosphate mineral. It contains some black manganese minerals.

Digitized by Google

Sample 85 (see table of complete analyses) was taken as a representative of this exposure, the size of which (as far as could be made out) was about that of a barrel.

R. A. Mast place.—About 8 miles south of Mountain City, and three-fourths of a mile southwest of Baker Gap postoffice, which is on Mill Creek, there is a small deposit of weathered residual phosphate rock on top of a hill on R. A. Mast's property. It is situated on the continuation of the same steep ridge over which the road passed from Mill Creek to the Mast place. The deposit lies practically on the contact of the Shady limestone and Watauga shale, southeast of the road. Just west of it, the Shady limestone outcrops, while east of it the Watauga shale sets in. The limestone is locally quarried and burnt for lime, and in the quarry occur limestones and calcareous shales, which are slightly phosphatic. The phosphatic rocks here led to the discovery of the more concentrated deposits described. To the northeast and southwest, on top of other hills which lie along this same contact, occur other less important phosphate deposits, such as that on C. R. Ward's place, just northeast of Baker Gap postoffice, which consists of weathered, cherty, siliceous, phosphatic material of residual origin. To the southwest, east of Dry Run Creek, this geological horizon continues to the Watauga River and some slightly phosphatic rocks have been found along this line.

Sample 46 was taken from surface residual float material on top of the hill on the R. A. Mast place. It represents only the weathered material of the surface. It consists of residual yellowish, somewhat porous and generally siliceous, phosphate rock, with the same appearance as that on the Baxter Gentry place, and contains more or less black manganese minerals.

East of Shouns.—The granitic rocks come into contact with the sedimentaries within a mile and a half east of Shouns Crossroads. In this area great disturbances have faulted and twisted the rocks in many ways, so that various ones come into contact.

On top of the ridge over which the road passes to Forge Creek, there are phosphatic deposits somewhat similar to the others described. In front of J. W. Wood's place, on the south side of the road, along the side of the hill, some brecciated

Digitized by Google

residual and shaly phosphatic material occurs. It probably is not of very great extent.

About a half mile north of the junction of Roaring and Forge creeks, on the north side of the stream, there is a patch of dolomitic limestone almost entirely surrounded by granites, faulted into that position. In the residual material of the decomposed limestones, intermixed with pieces of chert and sandstone rocks (the latter washed in from Forge Mountain) are scattered pieces of siliceous phosphate rock. The material is quite decomposed and is unmistakably a weathered product of the limestone. It is probably of very limited extent. There is a limestone quarry with a kiln here, and the quarry contains slightly phosphatic rock.

Sample 31 was taken as a representative of the surface residual phosphate on Jim Butler's place. The material consisted of light-yellow, rotten fragments containing specks and streaks of manganese.

Sample C was collected by the State Geologist from material thrown out of a dug well near what was known as Jackson's store on the road half way between Shouns and Rhea Forge. The phosphatic material was intermixed with yellowish porous shale. This locality is on the road, just below the hill on which is situated an old manganese prospect on the Virginia Iron, Coal, and Coke Company's land.

East of Roane Creek, between Rhea Forge and Mill Creek, along the foothills of Stone Mountain would seem to be a favorable locality for phosphate deposits. Although the writer found none, some have been reported east of Baker Gap postoffice.

DOE VALLEY AREA.

The third principal phosphate locality of Johnson County is in the valley of Doe Creek, which lies southwest of Mountain City, and constitutes one of the finest farming areas of the county. It does not, however, afford a railroad, and for that reason did not at first attract the phosphate prospectors as did the other regions.

Along the western side of Doe Mountain, in the foothills, lies a region similar both topographically and geologically to that of the eastern side in the vicinity of Maymead. In that

Digitized by Google

locality deposits of phosphate have been found at various places; but most of the phosphate is of disintegrated form and much is of a very low grade.

On the western side of the valley, the Shady limestone occurs along an anticline. The geologic as well as topographic conditions are quite similar to those of the Baxter Gentry place and Cold Spring region, but no phosphate deposits of any importance at all have yet been found there. That region, however, would be a favorable one in which to search for such deposits, and quite likely some will be found there in the future.

Sample 27 was taken on the Dyer property, 3½ miles southwest of Mountain City, about a quarter of a mile east of the road and 100 feet above it. The sample was collected from a clover field on the south side of a little hollow, up on the side of the hill not very far from a small limestone quarry. The phosphate consisted of residual, yellowish, earthy material mixed with loose soil and clay. The deposit is apparently situated near the contact of the Shady limestone and Watauga shale. There is another small deposit of phosphatic, clayey substance on the north side of the hollow. Probably there is no great quantity of this material and it is doubtful if any of it is of a very high grade. Its distribution over the fields in which it occurs seems to be of benefit as a fertilizer.

About 1 mile southwest of the Dyer place, on the hill back of the Nat Garland lime quarry, is a small deposit of phosphate. Farther to the southwest, other phosphate deposits are found, all of which occur very near the contact of the Shady limestone and Watauga shale.

Sample 33 was taken from a weathered surface exposure occurring on Tennessee Lloyd's farm, 7 miles southwest of Mountain City and one-half mile east of Doe Creek. The material was collected from a cut in a private road lying in a hollow not far from a limestone quarry and kiln. The rock was yellowish, earthy, weathered, more or less clayey, and somewhat siliceous. It was difficult to tell just what the original rock was. On either side of the deposit occur limestone and shale. It appears as though the phosphatic horizon was originally calcareous shale, which has been leached and disintegrated. The bedded rocks dip steeply toward the southeast, and there is an indica-

Digitized by Google

tion of an overturned syncline or a fault in this region. There is probably not a very great quantity or a very high grade of phosphate rock in this area, but most of the rocks contain a small percentage of phosphorus. The more phosphatic ones appear to be the more siliceous.

On the properties which adjoin Lloyd's place on the northeast and southwest are other small phosphate deposits. About 1½ miles southwest of the Lloyd locality, on E. C. Fritts' place, are several small deposits which are evidently the derived product of brecciated limestones and calcareous shales, as those are now exposed in a quarry on that place. Still farther southwest, one-half mile east of Pandora, on the top of a knob on the W. S. Lowe property, there is another deposit. Here yellow, brecciated phosphate rock of soft, residual nature was thrown up from small pits dug during the process of planting peach trees. The original rocks were limestones and shales of the Watauga shale formation. Although not very much investigation has been done in this region, and therefore no other phosphate deposits of importance are reported, it is very probable that other such deposits of phosphate may occur in the hills farther towards the southwest.

The phosphate rock of Doe Valley may prove to be of importance in supplying the local demand for phosphate fertilizer.

DOLOMITIC LIMESTONES.

Character.—The limestones of Johnson County have proved on analysis to contain a high percentage of magnesia. Limestones in which the weights of calcium and magnesium carbonate are nearly equal are known as dolomites. On the average, 40 per cent of the total magnesium and calcium oxide in the rocks from which all the samples analyzed were taken, is magnesia (MgO). The Bureau of Standards* show a range of from 25 to 45 per cent for dolomite. Since all these analyzed samples from Johnson County range from 26 to 43 per cent, they all fall well into the class of dolomites.

Economic value.—The calcium and magnesium carbonate in some of these rocks is over 98 per cent of the whole mass. The

*U. S. Bureau of Standards, Circular No. 30, 1911.

Digitized by Google

burning of lime is, therefore, quite well developed in the county. The lime is used almost exclusively for agricultural purposes, especially since the product may be made on the same land over which it is to be spread. Its great beneficial effect is very noticeable, but in places it has been applied in such large quantities as to burn out the humus of the soil and render the land apparently useless for several years. It is rather strange, however, that the large amount of lime that has been used in this county could have been applied to the land without more injury. The farmers use from 100 to 500 bushels per acre, which is about equivalent to 4 to 20 tons, for it is estimated that the lime averages 25 bushels to the ton. Of course different soils

FIG. 11. Quarry and lime kilns on Nat Garland's place at the head of Doe Valley, situated on the road 4 miles from Mountain City. This represents two burnt-out kilns. The one to the right retains the outside wall of logs. The one to the left is only a mass of white lime, most of which has been previously removed. The dolomite in this quarry (sample 50) runs 97.1 per cent calcium and magnesium carbonate. (O. P. J.)

are in need of different amount of lime, but in general agriculturists maintain that one or two tons per acre is sufficient. Below are given several possible reasons why the superabundance of lime applied has not done more harm to the soil:

1. The residual soil is deep and porous, and both surface and underground drainage is rapid.
2. Probably the rainfall is great enough materially to aid in rapidly changing the oxide or hydroxide of

Digitized by Google

lime into the carbonate form before it has time to act on the humus of the soil. It is a fact that rain, especially that first falling after dry weather, is charged with a certain amount of carbon dioxide, which would combine with the lime to form lime carbonate.

3. The lime may be drawn upon to neutralize great quantities of acids in the soil caused by the heavy rainfall.

Possibly the fact that the land is so little injured by what appears to be excessive liming is due to all the suggested processes. In addition, whatever the action of dolomitic lime on the land may be, it is possible that a larger amount of it may be used with impunity on a given area than of high calcium lime.

It is said that the first person to burn lime in Johnson County for agricultural purposes was Jesse Cole, who burned it in Shady Valley, about a generation ago. Probably before this time lime was made for building purposes. Shady Valley is a flat-bottomed cove surrounded by high mountains, and underlaid by limestone. The cove was formerly heavily timbered, but when cleared it was found to contain very acid soils which produced heavy crops after liming.

A great many small kilns are built every year by the farmers of Johnson County, usually during the fall and winter. The lime is generally left in the kiln to air-slake and rain-slake before it is removed. The best lime is usually white or gray and when slaked it pulverizes to a floury substance. In some kilns the rock which is quarried is quite siliceous and for that reason some of it forms clinkers. The product of the lime kiln is often in the form of lumps, which will not pulverize immediately after slaking, but will disintegrate in time after being spread on the fields.

The kilns are generally built in a box shape just below the place of quarrying. The sides are made either of logs or of quarried limestone, or rather dolomite, blocks. The points of firing are arched openings called "eyes" extending back under the kiln, and in these wood is burned. A kiln containing, for example, two eyes would be called accordingly a "two-eyed"

Digitized by Google

kiln, and the number of eyes in a kiln depends upon the size of the kiln. The most common sizes are two-, three-, and four-eyed kilns. It seems that about a week of continual burning, day and night, is required to make the lime.

FIG. 12. A lime kiln under construction, beside a bluff of rock to be quarried, on Scott Fritts' land one-half mile southwest of Fuller station. Note the three "eyes", where firing is to be done, built in an arched manner of blocks of dolomitic limestone. (O. P. J.)

The amount of slaked lime produced per eye is generally estimated to be about 1500 to 2000 bushels.

Although the cost varies in different localities, the following may be taken as generally true:

Approximate cost of burning lime.

Cost per bushel for quarrying and building kiln	2 cents
Cost per bushel for wood (fuel)	2 cents
Cost per bushel for blasting materials	1 cent
Total cost per bushel of air-slaked lime at kiln	5 cents

At 25 bushels to the ton, the cost would be $1.25 per ton at the kiln. The slaked lime is sold at 6 cents to 10 cents per bushel or $1.50 to $2.50 per ton at the kiln. The farmer loads this material in wagons at the kilns and hauls it to his land.

Digitized by Google

The writer recommends that the higher grade limestones and dolomites be pulverized,* and applied to the land in that form, especially where the limestone deposits occur on the railroad where shipping facilities are good. The cost of pulverizing is less than that of burning, and the effect on the land is more lasting than that of lime, and at the same time it does not burn out the humus of the soil. Besides ground limestone is much easier to handle. Furthermore, lime, after it is on the land, changes back into the original carbonate form, absorbing carbon dioxide from the atmosphere and rain. It must be borne in mind, however, that equivalent amounts of slaked lime and limestone is as 1 is to 1½. That is, 1 ton of slaked lime is equivalent to 1½ tons of ground limestone.

A few beds of dolomitic marble occur in Johnson County, but generally the rock is so full of fractures and seams that it would probably not be suited for many building purposes.

Geological occurrence.—The commonly used part of the Johnson County dolomitic limestone is in the Shady limestone. Many beds of lesser importance, generally not greater in thickness than 10 feet, occur in the Watauga shale.

Detailed descriptions of dolomites analyzed.—Sample 57 was taken as a representative of a 4-foot ledge of yellowish-gray, fine-grained, dirty looking dolomite, occurring in a bluff on the north side of the stream on Roy Philippe's land, 2½ miles northwest of Mountain City, and one-half mile southeast of the Baxter Gentry phosphate locality. The rock has been mapped by the United States Geological Survey as the Watauga shale. The rest of the bluff is composed of shales which are largely calcareous. Rock from this bed has been quarried and successfully burned for lime, and the lime has been used on the land and found to be quite strong. A piece of this same rock was burned in a local forge and pulverized. After being moistened with water and allowed to stand, the material hardened. The hardened mass was not very strong and could be crumbled on the edge with the finger. This crude test done in the field

*Since the writer was in Johnson County four small pulverizers are reported to have been installed there.

Digitized by Google

may, however, be an indication that some of the impure dolomites may prove to be natural cements.

Sample 43 was taken from the outcrop of a thin bed of dolomite on Morley's land, occurring in the Watauga shale one-fourth of a mile north of Mountain City on the end of the ridge which runs northward between the Furnace Branch and Cold Spring roads. The bed of dolomite is not fully exposed, but apparently is nearly 5 feet thick, stands almost vertical, and extends in a northeasterly direction, the strike following the ridge. It contains 77.4 per cent of the carbonates of calcium and magnesium.

Sample 37 was taken from the surface outcrop of an almost white, slightly pinkish dolomite of medium, even-grained texture, occurring on R. P. Donnelley's land. Although there is not a complete exposure here, this rock probably occurs in a considerable quantity. It is situated a short distance east of the Laurel dirt road in a small hollow on the side of the ridge drained by the Laurel, 3½ miles from Mountain City, and one-half mile north of the point where the road forks on the top of the ridge. The rock contains 98.32 per cent calcium and magnesium carbonate.

Sample 68 was taken from an outcrop along the east side of the Laurel dirt road, one-fourth of a mile north of Norman Wills' house, 1 mile southeast of Wills station, and about 4 miles north of Mountain City. The rock consists of dolomite, which contains 96.1 per cent calcium and magnesium carbonate.

Sample 70 was taken from an old quarry on the side of the hill in front of Jim Newt Wills' house on the Laurel road, north of the point where it crosses Dyestone Branch, one-half mile east of Wills station. At this place there occurs a cave, and near the opening of the cave are small deposits of carbonate of lime in the form of travertine or onyx marble, and stalactitic limestone. Besides this material there occurs a peculiar accumulation of very porous, siliceous and calcareous residium in which may be found imbedded shells of land snails, which evidently had died while crawling on this rock and later their skeletons were added to the mass forming nearby. On account of the phosphatic character of this material and its peculiar

Digitized by Google

residual deposition, this sample was collected for analysis. It shows a higher percentage of phosphatic matter than the surrounding dolomites on account of being partially concentrated.

Sample 103 was taken from a dolomitic marble occurring on the property of Baxter G. Wills, on the north side of the valley through which Dyestone Branch runs, about one-half mile southeast of Silver Lake, and a mile east of Wills station. This is probably the same bed as that found on R. P. Donnelley's place (sample 37), and similar to the dolomitic marble occurring one-fourth of a mile northeast of Silver Lake. The rock is hard, pinkish, rather fine-grained, compact, crystalline, dolomitic marble, and contains 98.3 per cent of the carbonates of calcium and magnesium.

Sample 14 was taken from a quarry which was built in connection with a local lime kiln on the property of Baxter G. Wills. It is situated next to the dolomitic marble just described (sample 103). The rock is dolomite, containing 98.18 per cent calcium and magnesium carbonate.

Sample 74 was taken as a representative of the general run of the dolomites occurring next to the mill on Silver Lake. This is an excellent situation for grinding rock, because of the local power obtained from the water of the mill. The sample contains 89.2 per cent calcium and magnesium carbonate. Although this rock is conveniently located, it is not the high grade material that will be found farther east in the hills in the form of dolomitic marble. Rock similar to samples 14, 103, and 37, will be found, no doubt, within one-fourth of a mile east of this locality.

Sample 49 was taken as a general representative of the beds exposed in Laurel Creek, one-half mile below Laurel Bloomery. The rocks reacted slightly to the field test for phosphate. This locality is on the narrow-guage railroad and one of the farthest north of the exposed dolomite areas in Johnson County. Analysis shows this rock to contain only a trace of phosphate and 86.3 per cent calcium and magnesium carbonate.

Sample 40 was taken from a fine-grained, light-gray dolomite, encountered when prospecting for phosphate on R. B. Brown's place near the trestle, just below the railroad, between

Digitized by Google

it and the dirt road, 1 mile northeast of Maymead. Clay, chert, and phosphate rocks were removed, and at a depth of 6 feet this rock was reached. It evidently represents the kind of rock from which the phosphate of this locality was derived by the leaching out of the soluble carbonates and the concentration of the insoluble silicates and phosphates. As the analysis shows, it contains only a little calcium phosphate, much silica, and only 85.07 per cent calcium and magnesium carbonate.

Sample 101 was taken on the side of the hill above the railroad northeast of the washer at Maymead on R. B. Brown's place. It occurs between the phosphate locality from which sample 63 was collected and a bluff of brecciated chert. The rock consists of a light-gray, highly brecciated, compact, fine-grained, hard rock, occurring in close association with the ordinary brecciated dolomites and cherts. It seemed to be partially leached and analysis shows it to contain a higher percentage of calcium phosphate than the limestones nearby. Its content in the carbonates of calcium and magnesium is 92.4 per cent. With this content and its content of calcium phosphate, which is 2.84 per cent, it would seem as though this would be very good rock to pulverize and apply to the land in the ground form.

Sample 64 was taken as a representative of the dolomite occurring in the quarry west of Maymead, back of the iron-ore washer on the side of the hill on the property of J. S. Vaught. The rocks here form a small, tightly squeezed fold. On the hill above them is the residual phosphate deposit, represented by samples 60 and 87. The sample shows 94.42 per cent of the carbonates of calcium and magnesium. There are other calcareous, slightly phosphatic shales lying above and interbedded with the layers of dolomitic limestones. These rocks probably represent the upper beds of the Shady limestone.

Sample 10 was taken from a quarry on the west side of Forge Creek, one-half mile northeast of the point where it empties into Roane Creek. The rock is dolomite and contains 90.53 per cent calcium and magnesium carbonate. This rock lies probably near the middle of the Shady limestone.

Sample 4 was taken from a quarry on the north side of Forge Creek near the point where it empties into Roane Creek. An-

Digitized by Google

alysis shows it to contain 96.9 per cent of calcium and magnesium carbonate.

Sample 50 was taken as a general representative of the quarry on Nat Garland's place, 4 miles from Mountain City on the road into Doe Valley. The rock is burned here on a larger scale than anywhere else in the county, and the lime produced is said to be one of the best for agricultural purposes. It contains 97.1 per cent calcium and magnesium carbonate.

Sample 51 was taken from a soft, peculiarly brecciated dolomite, occurring on the west side of Doe Valley, 1 mile west of Doeville, near the top of a low ridge. The rock reacted slightly to the field test for phosphate, and being porous it effervesced strongly in the nitric acid. The rock is composed of angular, subangular, and almost rounded fragments of gray dolomite, cemented loosely together by calcareous and siliceous material. The disintegration of the beds is very pronounced. Although no phosphate rock deposits have been found in this vicinity, it is probable that they may be present. The sample contains 78.27 per cent calcium and magnesium carbonate.

Sample 22 was taken as a representative of all the beds in the quarry back of the store at Shady, in Shady Valley, on the property of T. K. Garland. The rock is a dolomite and has been successfully burned for lime for agricultural purposes. It contains 96.92 per cent calcium and magnesium carbonate.

Sample 21 was taken from a quarry on the flat, level bottom of Shady Valley, one-half mile northwest of the quarry where sample 22 was collected, on the north side of the road. Rock from here was also removed and successfully burned for lime. It proves to be dolomite and contains 97.55 per cent calcium and magnesium carbonate.

Sample 52 was taken from a shaly limestone occurring in a bluff 2 miles southeast of Butler along the road which follows the north side of the Watauga River. The sample was taken in order to determine how much phosphatic material it contained. The field test indicated some phosphate, and the analysis shows it to contain only a trace.

Digitized by Google

high percentage of insoluble siliceous matter in the rock. The rock reacted slightly to the field phosphate test.

IGNEOUS ROCKS AND MISCELLANEOUS SAMPLES.

The bed of blue rock (amygdaloidal basalt) exposed along the east side of Iron Mountain, the various rocks in the granitic area along the east side of Johnson County, the granitic rocks along the western side of the Laurel Valley, and some of the older sandstones and shales, all contain a little phosphatic matter, in places. These rocks being largely insoluble will often be found to contain small amounts of phosphate, probably in the form of grains of the mineral *apatite*. The apatite may be the only mineral present in the rock soluble in the nitric acid of the field test, and if so, it is dissolved out and reacts to the test unhindered.

It is not at all probable that any rocks of this type in this region will ever prove to contain enough phosphatic matter to be of economic value; but they are of scientific interest, since they probably represent the original source of the phosphatic deposits in sedimentary beds of later ages. In the rocks analyzed the percentage of phosphate appears somewhat higher than in ordinary igneous rocks. Furthermore their phosphate content is fully as high as that in the dolomites, which on leaching gave place to the formation of the residual phosphate rock deposits.

Sample 3 was taken from a brownish, decomposed, granitic rock outcropping on the side of a hill, a fourth of a mile northwest of Wills, and about four and a half miles north of Mountain City. The rock occurred on Baxter G. Wills' property. It reacted slightly to the field test for phosphate.

Sample 11 was taken from a hard, bluish-green rock of much the same appearance as that on Iron Mountain (sample 15), which occurred in the bed of Forge Creek at the "Narrows", about 4 miles in an air line east of Mountain City. The rock is one of a number of dikes which cut irregularly through the *Cranberry granite* as mapped by the U. S. Geological Survey. The rock reacted to the field test for phosphate. To all appearances it has much the same composition as that of the amygdaloidal basalt of Iron Mountain.

Digitized by Google

Sample 15 was taken from a piece of bluish-green amygdaloidal basalt from Iron Mountain at the head of Timothy or Stout Branch, whose mouth is just below Pandora on Doe Creek, about 10 miles southwest of Mountain City. The material is a tough, hard, fine-grained rock containing scattering crystals of greenish minerals, occurring in small specks the maximum size of which is about that of a pea. In some places these amygdules are calcite crystals. In such a case, upon the addition of nitric acid, effervescence is produced as with limestone. This has caused certain prospectors to be misled in thinking the rock was a limestone, which it is not at all. Weathering of these more soluble amygdules has caused the surface of the rock to become pitted.

Sample F was taken by the State Geologist from this same amygdaloidal basalt of Iron Mountain.

Several samples of slightly phosphatic rocks were taken by the State Geologist in the region of the upper course of Roane Creek on the road to Trade. One of these rocks is of sedimentary origin and all the others are igneous, but all are located near the igneous and sedimentary contact, which consists of faults. None of the samples proved to contain any great amount of phosphatic matter.

Sample G was taken 7½ miles southeast of Mountain City on Roane Creek at Mayes Mill from a ledge of dark, shaly rock 12 feet thick, just across the road from the mill and 20 yards below the foot bridge, on land belonging to Alex Bumgardner. The rock from which the sample was taken lies between a 10-foot bed of shale on the upper side and a 50-foot bed on the lower side.

Sample D was taken from the right bank of the creek at the forks of the road just below Mayes Mill.

Sample H was taken a fourth of a mile above Loves Mill, on the north side of Roane Creek, 60 feet above the creek on land belonging to Alex Bumgardner. The rock is light-gray to dark-gray, and feldspathic, especially in the lighter parts. The sample was taken from a mass 50 feet thick.

Sample E was taken from the bed of the creek, 60 feet below where sample H was collected.

Digitized by Google

CONCLUSIONS.

1. The phosphate rocks of Johnson County may be used locally as ground raw phosphate.

2. The dolomitic limestones, which are abundant, favorably located, and, in places, of very high grade (that is, in lime), would be better pulverized for the land than burned into lime.

3. Pulverizers used for pulverizing one of these raw products may also be used to advantage in grinding the other.

4. The phosphate rocks occur in many pockets, scattered over the foothills of the main valleys, which lie near Mountain City.

5. There is a possibility of finding other deposits of phosphate in East Tennessee southwest of Johnson County, as well as in other places in that county itself. These deposits should be found in the geological horizons, mapped by the United States Geological Survey, as the Watauga shale and Shady limestone, but principally near the contact of these two formations.

6. With the data that may be obtained from the surface exposures and from the prospects already made, it appears that the phosphate is generally too low grade to be of wide commercial use at present. If the time should come when rock running 25 to 50 per cent bone phosphate of lime is marketable, either as ground rock or as superphosphate, these deposits may be profitably utilized.

7. Further extensive and careful prospecting will have to be done in order to determine more exactly the real value of the field. Also one or more of the deposits should actually be mined to show an example of the actual contents of a typical deposit. This mining could be carried on in connection with pulverizing for local need and experimentation.

8. Most of the phosphate rocks of Johnson County are buff, yellow, and reddish-brown, and, in places, white and dark-brown breccia, often laminated in texture. Much of the material is so thoroughly weathered that it is quite soft, but some of it is very hard, having the misleading appearance of chert. At one locality—the E. E. Butler place—there is a peculiar dark bluish-black, very hard and tough rock.

Digitized by Google

9. Chemically, calcium (Ca) forms the base of the phosphate. Fluorine (F) is present in amounts varying from about 1 to 1½ per cent. Carbon dioxide (CO_2) is also present, in amounts varying from a fraction to nearly 3 per cent, and appears to vary pretty closely with the fluorine. Insoluble siliceous matter runs rather high, while iron and aluminum oxide are not much above the commercial limit, averaging about 5 or 6 per cent.

10. The so-called limestones of Johnson County prove to be highly magnesian, and all those analyzed fall well into the class of dolomites, many of which are very high in content of calcium and magnesium carbonate.

11. The dolomites, as well as some of the shales, are shown by analysis to contain from a trace to over 2 per cent lime phosphate.

12. The principal phosphate rocks, some of which run over 60 per cent lime phosphate, were probably formed by the weathering of these slightly phosphatic beds of carbonate rocks, and possibly by the replacement of some of the shales.

13. The factors effecting the leaching and weathering are: The time during which the process has been operative; the fracturing of the beds; the character, structure, and association of the beds with the surrounding less soluble rocks; topography; vegetation; precipitation and other climatic conditions.

14. The phosphatic matter in the sedimentary beds was probably originally derived from the old land mass of igneous and sedimentary rocks. These prove by the analyses to contain a considerable quantity of disseminated lime phosphate.

Digitized by Google

SLIGHTLY PHOSPHATIC SILICEOUS DOLOMITIC LIMESTONES AND SHALES.

The field test for phosphate is very delicate, in fact too delicate to determine which rocks are phosphatic enough to be considered of economic value. It seems that the more soluble a rock is in nitric acid the more difficult it becomes to recognize its relative phosphatic content. For instance, a limestone effervesces when nitric acid is placed on it and thus interferes with the yellow phosphomolybdate reaction, while in the case of a slightly phosphatic siliceous rock, such as a hard shale, the test apparently indicates a rather large percentage of phosphate, though the amount may be small.

The following analyses are made from rocks which have proved to be of no particular commercial importance. In certain cases they show from what sort of rocks some of the low grade, highly siliceous phosphate rocks were derived. In all cases they will prove to be of value to the prospector by teaching him not to be misled by every phosphate-bearing rock. Such slightly phosphatic material may, however, assist one in the discovery of higher grade material.

Sample 36 was taken from a 4-foot layer of black shale overlying dolomitic limestones in the quarry on the J. S. Jenkins property near Cold Spring. The quarry is situated near the top of a hill, within 200 yards of one of the prospect pits for phosphate. The black shale reacted to the field test for phosphate and may be one of the beds which, when decomposed, formed the phosphatic clay in some of the prospect pits. The beds in this quarry lie practically horizontal, which is peculiar in this country, and is probably due to the fact that in this place lie at the top of the local dome structure of the rocks. On top of the hill above the quarry occurs some residual phosphate rock and limestone. The black shale is easily recognized and can be used as a geological bench-mark. It lies very near the contact of the Shady limestone and Watauga shale. Above it lie transitional shaly limestone beds, and below it massive dolomitic limestones.

Sample 1 was taken from a bed of hard, impure dolomite overlying a better grade of dolomite in a hollow just over a small hill southwest of Silver Lake, east of the road, on the

Digitized by Google

property of Baxter G. Wills. The sample reacted distinctly to the field test for phosphate. The ledge from which it was collected had been formerly tested in the kiln and would not turn to lime after being burned, as did the underlying rocks. From the analysis it is evident that the high content of silica prevented the rock from acting like a regular dolomite or limestone.

Sample 7 was taken from a calcareous shaly rock closely associated with residual phosphate rock in an exposure along the road to Silver Lake, on Baxter G. Wills' land, about one-half mile east of Wills station. The geological horizon of this rock is about on the contact between the Shady limestone and Watauga shale. The rock is a pinkish-gray shaly material, dipping about 50° towards the northwest. It reacted slightly to the field test for phosphate.

Sample 19 was taken from a quarry for a lime kiln on Tennessee Lloyd's place, one-half mile east of his house, 7 miles southwest of Mountain City, in the foothills on the northwestern side of Doe Mountain. The rocks in the quarry contained too much silica to make much lime. Burning caused much of the material to clinker. It reacted, however, to the field test for phosphate.

Sample 20 was taken as a general representative of the slightly phosphatic rocks occurring in a cut in the private road on T. Lloyd's place, just below where sample 19 was collected. Out of this same mass of rocks was picked a sample of phosphate rock, indicated as sample 33.

Sample 35 was taken from a phosphatic shaly limestone occurring in a bluff at the mouth of Boiling Spring Hollow on Milton E. Wilson's land, not far from Lloyd's place on the south side of Doe Creek, about 7 miles southwest of Mountain City. The rock reacted fairly well to the field test for phosphate, but from the analysis it is evident that it contains very little phosphatic matter, but instead a larger amount of insoluble siliceous material.

Sample 23 was taken from a small ledge of gray limestone in Shady Valley, one-fourth of a mile north of Shady on Floyd McQueen's land. An attempt was made to burn this rock for lime, but resulted in a failure, due to clinkering caused by the

Digitized by Google

Digitized by Google

Digitized by Google

Structure of the Southern Part of Cumberland County, Tennessee, in Relation to the Possible Occurrence of Oil and Gas

By Chas. Butts.

The occurrence of petroleum at Spurrier,[1] in Fentress County, about 30 miles north of Crossville, which is in Cumberland County; at Rugby,[1] an equal distance northeast of Crossville, as developed 20 years ago; and the more recent discovery of oil in the vicinity of Oneida, Scott County,[2] naturally suggests prospecting for oil in other parts of the Cumberland Plateau. Since geologic structure is an important condition affecting the accumulation of oil in so-called pools in the rocks, it is believed that it would serve the interest of would-be prospectors to publish the accompanying structure map and general section of the southern part of Cumberland County, in advance of the publication of the more general report, for which they were prepared. The map and section include all descriptions necessary for their understanding.

As to the possibility of oil or gas it may be said that the rocks carrying oil to the north and northeast outcrop in Sequatchie Valley, so near to all parts of the Plateau that it seems probable that the oil, if any ever existed here, has long ago escaped, or if any still remains, that indications of the same would appear at the outcrop of the oil-bearing strata. In this connection, the further fact may be stated that in Pennsylvania no gas in commercial quantities occurs within 20-25 miles of the Allegheny Front and no oil pool occurs within a much greater distance from the Front. As far as possible influence on the occurrence of oil and gas in the rocks to the west is concerned, the Allegheny Front corresponds to the escarpment on

[1] Campbell, M. R., U. S. Geol. Surv., Standingstone Folio, No. 12.

[2] Glenn, L. C., Recent Oil Developments Near Oneida, Scott County, Tennessee, Tenn. Geol. Surv., *Res. of Tenn.*, Vol. V, No. 4, October, 1915.

Digitized by Google

the east side of Walden Ridge and to the escarpments bordering Sequatchie Valley. Another feature of importance should also be pointed out, and this is the faults in the central part of the Crossville quadrangle.* These are other avenues through which oil and gas may have escaped. Nevertheless, while the probabilities seem distinctly unfavorable to the occurrence of oil and gas in commercial quantities in this region, there is no certain proof, one way or the other, except the drill.

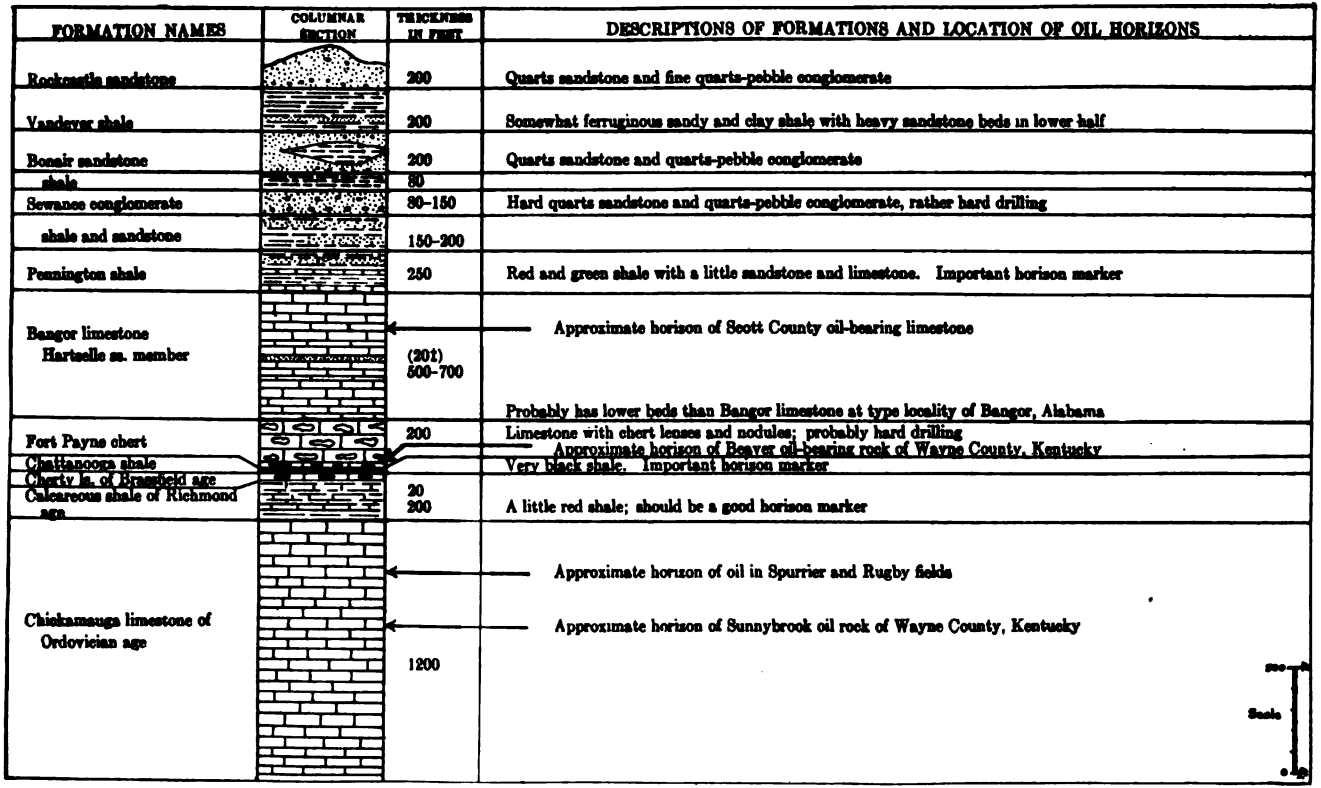
It is a fact, established by observations in many oil and gas fields, that structure or lay of the rock strata has a large, and perhaps controlling, influence on the accumulation of these substances. Gas accumulates on the tops of the anticlines or upward-bending folds, and oil lower down on the sides of the folds or flanks of the synclines or downward-bending folds. In the southern part of the Crossville quadrangle, such favorable structure exists, as shown on the accompanying map. The most favorable locations for gas would seem to be along the line indicated by the broken lines on the map, passing through Vandever and Lantana, which represent the axial lines of the anticlines. Oil, if present, would most probably be encountered down the slopes of the beds beyond the gas zones toward the synclinal axes also shown by broken lines. In the Crossville quadrangle the horizon of the different oil-bearing strata or "sands" of the region to the northward, as indicated on the general section, lie at depths varying from 1100 to 2300 feet below the surface at Vandever and 300 feet less at Grapevine. A well at Grapevine would start at the top of the Bonair sandstone.

The structure contours on the accompanying map are drawn on the top of the Vandever shale. The contour interval is 50 feet. Each contour line is supposed to pass through points on the top of the Vandever shale, having the same elevation above the sea level. Thus the 1750-foot contour passes through points 1750 feet and the 1800-foot contour passes through points 1800 feet above sea level. Altogether the contours show the position, shape, and magnitude of the anticlines and synclines.

---

*The Crossville quadrangle is the one represented by the maps accompanying this paper.

Digitized by Google


FORMATION NAMES
COLUMNAR SECTION
THICKNESS IN FEET
DESCRIPTIONS OF FORMATIONS AND LOCATION OF OIL HORIZONS
Rockcastle sandstone
200
Quarts sandstone and fine quarts-pebble conglomerate
Vandever shale
200
Somewhat ferruginous sandy and clay shale with heavy sandstone beds in lower half
Bonair sandstone
200
Quarts sandstone and quarts-pebble conglomerate
shale
80
Sewanee conglomerate
80–150
Hard quarts sandstone and quarts-pebble conglomerate, rather hard drilling
shale and sandstone
150–200
Pennington shale
250
Red and green shale with a little sandstone and limestone. Important horizon marker
Bangor limestone
Hartselle ss. member
(201)
500–700
Approximate horizon of Scott County oil-bearing limestone
Probably has lower beds than Bangor limestone at type locality of Bangor, Alabama
Fort Payne chert
200
Limestone with chert lenses and nodules; probably hard drilling
Approximate horizon of Beaver oil-bearing rock of Wayne County, Kentucky
Chattanooga shale
Very black shale. Important horizon marker
Cherty ls. of Brassfield age
20
Calcareous shale of Richmond age
200
A little red shale; should be a good horizon marker
Approximate horizon of oil in Spurrier and Rugby fields
Approximate horizon of Sunnybrook oil rock of Wayne County, Kentucky
Chickamauga limestone of Ordovician age
1200
Scale

Generalized section of the rocks in the southern part of Cumberland County, Tennessee, showing the rocks that would be penetrated by a well 2200 feet deep located at Vandever.

Note: A well at Grapevine would start at the top of the Bonair sandstone.

Digitized by Google

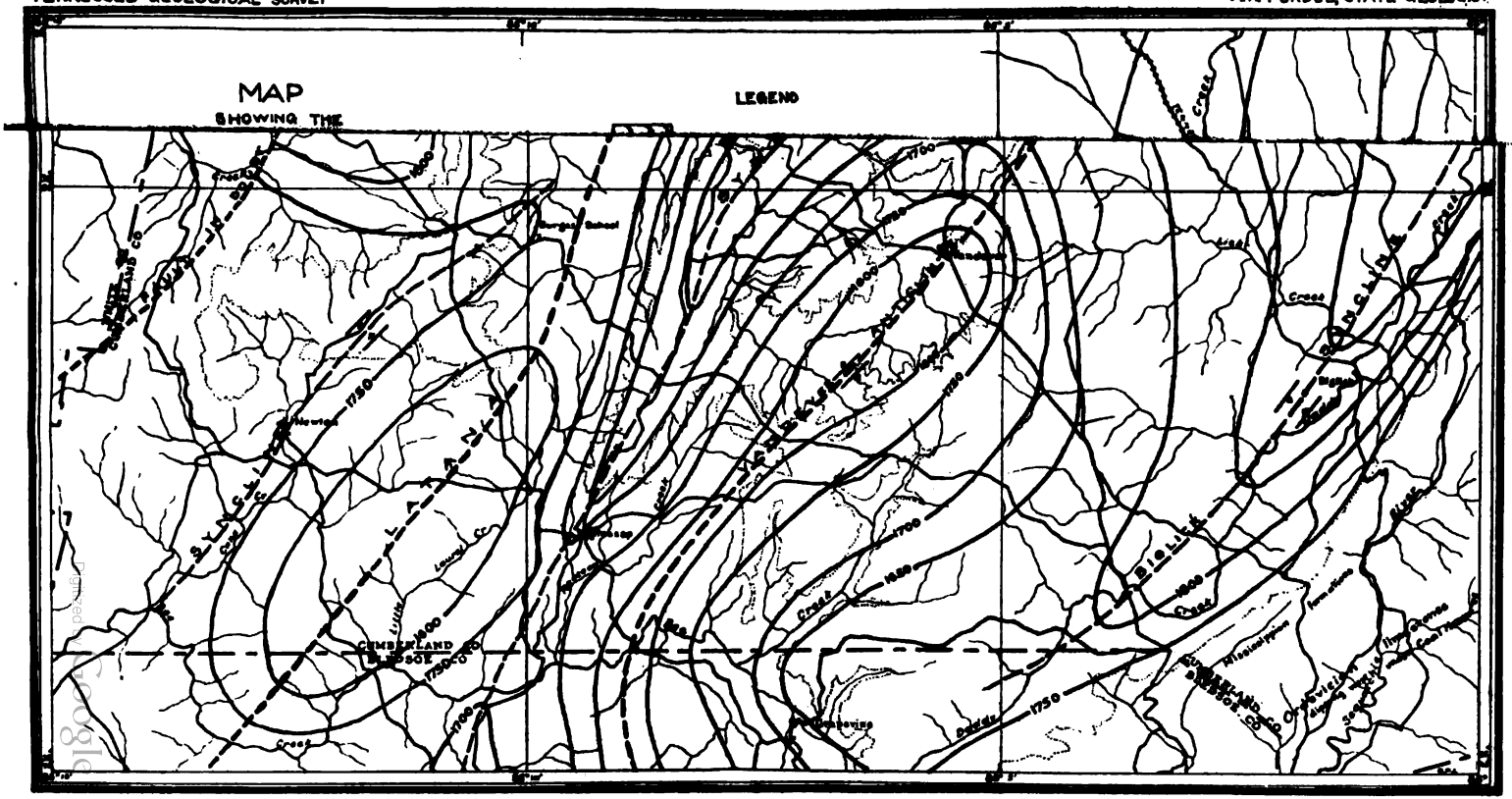
The nearest railway stations to the region mapped are Crossville, on the Tennessee Central Railroad, and Clifty, the terminus of the Sparta branch of the Nashville, Chattanooga, and St. Louis Railway. Crossville is about 10 miles somewhat east of north from Vandever, and Clifty is an equal distance northwest. Also Vandever is about 20 miles north of Pikeville, in Bledsoe County, the terminus of another branch of the Nashville, Chattanooga, and St. Louis Railway. The road to Crossville is direct and fairly good; that to Clifty is roundabout and rougher. The main roads within the region mapped are fairly good.

The region is well timbered and fairly well watered, and coal is obtainable from country banks a few miles either eastward or westward from Vandever, or could be hauled from the mines at Clifty.

Digitized by Google

TENNESSEE GEOLOGICAL SURVEY

A.H. PURDUE, STATE GEOLOGIST



JF
WICH.

Digitized by Google

Notes on Manganese in East Tennessee

By A. H. Purdue.

The common ores of manganese look a good deal like brown iron ore and would be taken for such by most persons. When broken, the fresh surfaces of manganese often have a bluish shade, which iron ore does not have; and when ground to a powder, the common ores of manganese are iron-black, while iron ore so ground is brown or red. These are simple tests that any one can use if there is doubt as to whether a mineral is iron or manganese.

Manganese is used chiefly in making *spiegeleisen* and *ferromanganese*, which in turn are used in the manufacture of Bessemer steel. These are both forms of *pig iron; i.e.*, iron produced in a blast-furnace. The difference between the two is not clear, but in general if the pig iron contains from 8 to 20 per cent of manganese, it is called spiegeleisen, and if more than that amount, it is called ferromanganese.

"Other uses of manganese are in the manufacture of chlorine, bromine, oxygen, disinfectants, driers for varnishes; as a decolorizer to remove the iron green color from glass and also, when added in larger quantity, to give an amethystine color to glass and pottery; in the ordinary dry battery; in calico printing, making green and violet paints, etc."*

Manganese is derived from manganese ores, from manganiferous ores, and from manganiferous zinc residuum. The first is mined for manganese alone; the second, for iron or silver, and manganese; the third is a residuum in furnaces using New Jersey zinc ores, and consists largely of iron and manganese oxide.

The amount of manganese produced in the United States is not large, though it occurs in greater or less amount in eighteen of the states. In 1914, this country produced 2,635

**Elements of Mineralogy, Crystallography and Blowpipe Analysis*, by Moses and Parsons, Fourth ed., p. 227.

Digitized by Google

long tons.* The average price per ton was $10.77. It came mainly from California, South Carolina, and Virginia, with Virginia far in the lead. In the same year, the amount of manganese imported was 283,294 long tons. This came mainly from Russia, Turkey, and Brazil. Most of the manganese ore that has been produced in the United States has come from Arkansas, Georgia, and Virginia, though Arkansas has not produced much since 1898, nor Georgia since 1903. Virginia has been a rather constant producer. Tennessee has never been a great producer of manganese, the total output since 1886 being only 2,475 long tons.

The amount of manganiferous ore produced in the United States in 1914 was 445,827 long tons. This came from Arkansas, Colorado, the Lake Superior region, and Virginia. The manganiferous zinc residuum produced in 1914 was 100,198 long tons.

The approximate amount of manganese ore imported in 1915 was 312,298 tons, an increase of 30,612 tons over 1914. About 81 per cent was imported in the last half of the year, nearly all coming from Brazil.† This increase, with the time at which it occurred, shows the quick response that was made to the demands upon us from the European War.

The demand for manganese at the present time may be judged from the fact that in 1913 the price of ferromanganese varied from a minimum of $49.96 to a maximum of $76.95 per ton, while now (March, 1916) "there are reports of transactions at as high as $400."‡

DESCRIPTION OF DEPOSITS.

In East Tennessee, manganese deposits are known to occur in several places from Bradley County in the southern part, to Johnson County in the northeastern corner.

Bradley County.—The deposits in Bradley County have been described by Mr. W. A. Nelson§ as occurring on the east slope

*The statistics given herein, unless otherwise stated, were taken from reports of the U. S. Geol. Surv.

†*Eng. and Min. Jour.*, Vol. 101, No. 6, p. 284.

‡*Loc.* cit. No. 12, p. 543.

§*Resources of Tennessee*, Vol. 1, No. 6, pp. 220-228.

Digitized by Google

of White Oak Ridge, some 8 miles west of Cleveland. The deposit lies in a belt a half mile wide and 2½ miles long, near the Bradley-James County line, and parallel to it. The ground has been prospected in several places, and the indications are that the ore will be found within 50 feet of the surface. The ore is both pyrolusite and psilomelane, occurring in chert, and associated with the iron ore, limonite. The overburden is sandy clay, 10 feet deep and less, much of which contains numerous lumps of manganese.

The mines should be worked by the open pit method. Water would be supplied by springs, and wood is near at hand for fuel. The property is owned by Mr. J. H. Artz, of Cleveland, Tenn.

Monroe County.—Manganese ore has been described by Burchard* and others as occuring in connection with iron ores, 1½ to 3½ miles northeast of Sweetwater, in residual material of the Knox dolomite. The following analysis shows the average composition of the ore:

Average analysis of manganese ore from Sweetwater, Tenn.†

Manganese	45.00 to 50.00
Iron	3.00 to 8.00
Phosphorus	.125 to .15

Sevier County.—The following was supplied by Dr. C. H. Gordon, Professor of Geology in the University of Tennessee, Knoxville:

"The deposits of manganese here described are located on the south side of East Fork of Little Pigeon River about 8 miles east and a little south of Sevierville. They have been opened in two places, one on the north, the other on the south slope of a spur or ridge extending nearly east and west and bounded by two small valleys which open eastward into the main valley of East Fork.

"The country rock is the Knox dolomite, which occurs in massive beds dipping at an angle of 30 degrees to the southeast (S 50 E). The dolomite is overlain by a formation of slate,

*Burchard, E. F., State Geol. Surv. of Tenn., Bull. 16, pp. 52-58.

†Weeks, J. D., 16th Ann. Rept., U. S. Geol Surv., pt. 3, 1895, p. 424.

Digitized by Google

which outcrops in the slopes of the ridge and along the valley bottom a short distance east of the ore banks.

"The ore bodies are tabular, and stand nearly vertical with the long axis extending about south 40 degrees west or nearly parallel with the strike of the dolomite. The ore body on the north slope of the ridge has been opened by a trench about 150 feet long to a depth of 15 or 20 feet. The width of the opening is variable, ranging from 5 to 10 feet. It is now partly caved in and the exact width of the ore body could not be ascertained. For the same reason its vertical extent could not be learned. A considerable amount of ore has been removed here, though a sheet of ore from 6 inches to a foot thick still covers the east face of the trench. Southwestward the ore pinches out in the dolomite. To the northeast the slope is covered, and the extent of the ore body in that direction is unknown.

"The ore body on the south slope is similar in form and parallel with the first, but lies on a different belt, apparently about 100 yards to the southeast. It has been opened by a trench and tunnel for a distance of 150 feet into the hill, where it is cut off by the dolomite.

"The ore consists chiefly of hard amorphous *psilomelane* or hydrous manganese oxide with which there is likely to be associated a small amount of the anhydrous oxide, *pyrolusite*. The ore occurs in cellular masses in clay, with clay occupying the spaces. Where the ore remains in the north trench it lies close against the face of the dolomite with very little clay between. On the opposite side of the trench it grades into clay. The clays associated with the ores are manganiferous, and more or less iron ore occurs in connection with the deposits. The iron ores appear to have been worked to some extent in this vicinity in the early days.

"Like some other known deposits of manganese in East Tennessee, these represent concentrations in residual clays overlying the Knox dolomite. Practically all deposits of manganese are of this character. The Sevierville deposits are interesting in that they appear in a nearly vertical tabular form suggestive of vein formation. This is due to the fact that they occupy depressions in the dolomite apparently caused by solution along lines of fracture."

Digitized by Google

The following analysis is given by Bailey Willis in the Tenth Census* of the United States for manganese ore collected on Little East fork of Little Pigeon River, 13½ miles east of Sevierville, among the outliers of the Unaka Mountains.

Analysis of manganese thirteen and a half miles east of Sevierville.

Metallic iron	6.48
Phosphorus	0.097
Manganese oxide	59.73

The ore was associated with limonite, which occurred in a bed extending half a mile to the southeast across several spurs of Bear-Wallow Mountain.

Cocke County.—Some 20 years ago, a Captain Smith located a deposit of manganese 150 feet above the base of English Mountain, 5 miles southwest of Newport. At that time, it was prospected somewhat, then abandoned until August, 1915, when it was reopened by Messrs. L. E. Patton and Paul Lanier, of Birmingham, Ala. The deposit is on what is known as the Yellow Springs mine, Spence property, or the Red Mack farm.

The ore occurs in red, tough, residual clay, the thickness of which is not known, but it is perhaps not less than 60 feet. The development consisted of an open cut 100 feet long and 25 feet deep, at the inner end, and two tunnels driven into the hill, 20 feet beneath the open cut. In the pit, the clay carrying the ore dips to the south from 50 to 60 degrees, and appears to be about 15 feet thick. This suggests that the ore occurs in certain beds that have disintegrated. The rock beds in the mountain above the prospect, dip to the north at a high angle. The south dip of the ore probably is due to the down-hill creep of the upper part of the clay. If so, and if the ore is confined to certain layers, the dip will change to the north as it is gone down on. It would be well for those mining the ore to keep this in mind, else they might lose it.

One of the tunnels is only 15 feet long, and showed only a small amount of soft manganese in little fragments mixed through the clay. The other, which appears to have produced ore, was locked up at the time of the writer's visit, the mine

*Vol. 15, Mining Industries, p. 336, 1880.

Digitized by Google

having been shut down from the financial failure of the operators.

Carson Creek, at the base of the mountain, contains an abundance of water for purposes of washing the ore, and the mountain side is covered with timber for fuel. A bin at the foot of the mountain contained about 10 tons of washed ore, when the property was abandoned. In addition to this, several tons had been shipped to Birmingham.

A quarter of a mile east of the above prospect, which direction is on the line of the strike of the rock beds in the mountain, across the hollow of Carson Creek and perhaps 250 feet above it, there are three old prospect pits dug by a Captain Smith, 20 years ago. Around these pits, there are chert fragments, filled with a net-work of thin manganese veins. The sides of the largest of the pits contain pellets of manganese, in the clay.

On the crest of this ridge, which is a spur running north from English Mountain, from 50 to 100 feet above the pits, the clay at the surface along a trail is filled with small pellets of manganese, and fragments of a pound or more sparingly occur on the surface. The depth of the residual material here is not known, but it probably is not less than 40 to 60 feet. The property deserves prospecting. It is owned by ex-Governor Ben W. Hooper, of Newport, Tenn. The underlying rocks of this and of the Spence property are of Cambrian age.

"Other deposits in this district are reported from Neddy Mountain and Long Creek, 3 miles and 5½ miles respectively, east of Bridgeport; from Del Rio, Wolf Creek, and Cosby, all in Cocke County."*

Hamblen County.—Five miles west and south of Morristown, on land owned by Mr. Harry Douglass of that city, there is a prospect shaft for manganese, sunk 15 feet deep in the residual clay. The formation is mapped by Mr. Arthur Keith of the U. S. Geological Survey, as Knox dolomite. The shaft is sunk through rocky, talus material, consisting of chert and sandstone. The sandstone is well charged with manganiferous iron, full of sand. Such fragments are common on the surface, in

*Harder, E. C., U. S. Geol. Surv., Bull. 427, p. 76.

Digitized by Google

the field where the shaft is sunk. Besides the ore occurring in the sandstone, there are small masses of iron containing much insoluble material, and small nodules of manganese ore.

South and west of the above prospect, perhaps 2 miles on land owned by William Cowan, R. R. No. 1, Morristown, Tenn., there is a manganese prospect at the top of one of the highest hills of the region. It is in a field, in residual material of what is mapped by the U. S. Geological Survey as the Knox dolomite. The prospect consists of a pit running with the contour, 125 feet long and 5 feet deep. The material is red clay full of brecciated chert cemented with manganese oxide. The prospecting is reported to have been done by Mr. James Henry, of Marion, Ky. It is also reported that an analysis of a sample ran 55 per cent oxide of manganese, 1 per cent iron, and low in phosphorus. This property should not be abandoned without further prospecting, as it is very probable that it contains pay ore, provided the ore can be separated from the chert. After breaking with the hammer, the large pieces of ore could be hand picked. The prospect is located 1½ miles north of Panther Springs, and 2½ miles from Alpha, on the Southern Railway. Panther Creek, flowing from Panther Springs, probably would supply an abundance of water for washing the ore, but of this the writer is not assured, as he has not seen the creek.

Unicoi County.—A manganese prospect is reported on Scioto Creek, 4 miles from Unicoi, on land owned by Mrs. W. H. Brummett. The writer has not seen this property, but is informed that quite a quantity of ore has been taken out and is now at the prospect. Manganese is also reported on adjoining land owned by Mr. Isaac Britt.

Carter County.—One and a half miles northeast of Marbleton, in a clump of trees at the top of a hill on land owned by Mr. M. C. Tipton, there are two shallow pits that were dug for manganese some twelve or fifteen years ago. This is near the Carter-Unicoi County line. They are in red, tough clay that from the outcrops on the hillside, appears to be 40 feet thick. The clay is residual from limestone beds that stand on edge, and which probably belong to the Knox dolomite, though they may be a part of the Honaker limestone, which is of Cambrian age.

Digitized by Google

The ore is rather thickly distributed on small fragments through the clay, though pieces were taken out that will weigh 30 pounds. It is quite free from siliceous material. This property should be prospected deeper. The area that should be prospected will cover from 1½ to 2 acres.

On the side of the mountain, southeast of the town of Hampton and 400 feet above it, there is an old iron mine that was worked before and during the Civil War. The ore was used in a furnace at the foot of the mountain, on Doe River. It occurs in red clay, residual from the Shady limestone, which is of Cambrian age. The thickness of the clay is not known, but one of 100 feet would not be astonishing. The ore is manganiferous iron. The old pit is 200 feet long, 150 feet wide, and 25 feet deep, and is grown up in trees 10 to 20 inches in diameter. A similar pit is reported a quarter mile west of this one.

This property should be prospected by starting in 150 feet below the old pit, and digging a deep trench up the slope, or by sinking shafts at different levels. The prospecting should continue downward to the surface of the limestone, not only to test the ground for iron and manganese, but also in quest of zinc ore, which may occur in good quantity just above the limestone.

A complete analysis of manganese ore from Stony Creek Valley, which lies just southwest of Shady Valley, in Johnson County, is given by Bailey Willis in the Tenth Census* of the United States. Stony Creek Valley lies between Holston and Iron mountains and is reached by a branch of the Virginia and Southwestern Railroad from Bristol and Elizabethton. The sample was taken many years ago from the Hodge bank; its analysis is as follows:

Analysis of manganiferous iron ore from the Hodge bank.

SiO_2 (silica)	3.38
Fe_2O_3 (Fe, 34.28) (iron, peroxide)	48.95
Al_2O_3 (alumina)	2.38
MnO (manganous oxide)	2.72
MnO_2 (manganese dioxide)	32.29
CaO (lime)	0.56

*Vol. 15, Mining Indusries, p. 345.

Digitized by Google

MgO (magnesium oxide)	0.17
FeS_2 (iron disulphide)	0.041
NiS (nickel sulphide)	0.18
CoS (cobalt sulphide)	Trace
CuS (copper sulphide)	Trace
CO_2 (carbon dioxide)	0.25
SO_2 (sulphur dioxide)	0.02
P_2O_5 (phosphorus pentoxide)	0.166
C (carbon in carbonaceous matter)	0.04
H_2O— (hygroscopic water)	1.14
H_2O+ (water of composition)	7.89
	100.177

Johnson County.—The following notes on manganese in Johnson County were supplied by Olaf P. Jenkins:

Minerals of manganese are very commonly distributed over Johnson County, occurring in residual material of the more easily weathered Cambrian rocks, especially in the formations mapped by the United States Geological Survey as the Shady limestone and Watauga shale. In many places deposits of manganese occur near the contact of the Shady limestone and Erwin quartzite. The limonite (iron ore) deposits of this county often contain some manganese minerals. Investigation of manganese should be made in this county in connection with investigation of iron.

Around the edge of Shady Valley, a cove lying between Holston and Iron mountains, reached by the Beaverdam Railroad from Damascus, Virginia, are irregular residual deposits of manganese and manganiferous iron ore, that were prospected and partly mined many years ago. According to some statements of the residents there, more or less manganese ore was mined here and hauled by wagon to Bristol, but the work seems to have been primarily for the iron. The old pits are filled up, and to secure an idea of the amount present, prospecting would be necessary. These pits may be found at several places, as near Crandull; on the western side of the valley beside the Mountain City and Bristol road; and in several places in the southern end of the valley. All of these deposits occur very near the contact of the Shady limestone and Erwin quartzite. They are to a greater or less extent covered by washed-in bowlders of sandstone, as well as grown over by thickets. The

Digitized by Google

mineral rights on these lands have evidently been taken up principally by the Empire Lumber and Mining Company of Philadelphia, and by Mrs. J. J. Wright.

A compilation* was made by the United States Geological Survey† of information regarding the manganese ores in Shady Valley, which is as follows:

The ores of Shady Valley, mainly brown iron ores, subordinately manganese, occur in residual clays of the quartzite, shale, and limestone. The iron ores have been worked for a long time, but the manganese ores have been merely prospected. The manganese occurs as steel-gray or black amorphous psilomelane in porous masses of stalactitic branches, and in kidneys. Crystals of pyrolusite line some of the cavities in the massive ore.

The iron and manganese ores are found interbedded in lenticular layers or pockets. In some places they occur together in the same pocket, and elsewhere they are separate. The iron-ore beds are a few inches to 10 feet thick; the manganese ore beds are a few inches to 3 feet thick.

The most important showings of manganese in Shady Valley‡ are at the Heberlin mine and its vicinity. About 800 tons of ore, which is mainly psilomelane, have been taken out, but none has been shipped. At the Wright opening near the head of the valley, ore occurs in the massive form in a bed 6 feet thick. About 150 tons have been mined. Another deposit occurs in a small stream about a mile from the Wright opening, where a ledge of manganese ore 4 feet wide and 6 feet deep is exposed. Manganese ore has also been found in several places on the Sheafer property in the lower end of the valley, and at numerous localities in association with iron ore. Among the latter it occurs principally at the King, Blevins, and Silver banks.§

*Partly from Penrose, R. A. F., Jr., *Manganese: Its uses, ores, and deposits:* Ann. Rept. Arkansas Geol. Surv. for 1890, Vol. I, 1893, pp. 414-416.

†Harder, E. C., Manganese Deposits of the United States, Bull. 427, pp. 73-74, 1910.

‡Weeks, J. D. Seventeenth Ann. Rept. U. S. Geol. Surv., pt. 3, 1896, pp. 202-203.

§Willis, Bailey, Tenth Census, U. S. (1880), Vol. 15, Mining Industries, pp. 344, 345.

Digitized by Google

The following are analyses of ores from Shady Valley* and vicinity:

Analyses of manganese ores from Shady Valley.

	Silica	Iron	Manganese	Phosphorus
Heberlin mine	1.62	4.6	51.05	0.075
Do	1.1	3.0	55.00	.099
Do†	1.30	2.085	53.735	.008
Alexander Coles	1.4	2.3	53.09	.177
Wright bank	7.6	7.1	41.44	.066
Sheafer bank	4.12	5.2	50.25	.16
King bank	1.7	16.1	40.87	.16

In Doe Valley, which lies between Iron and Doe mountains, southwest of Mountain City, occur a number of small deposits to which very little attention has been given. Float ores of manganese occur in the foothills of Doe Mountain. There is a deposit which makes a good surface showing on top of a hill 8 miles southwest of Mountain City just west of the road and Doe Creek, near the site of an old forge on land owned by E. C. Fritts. It is said that 50 years ago this material was thought to be iron ore, was prospected, and some of it was removed from a depth of 6 feet. Attempt was made to burn it in the forge, which resulted, of course, in failure.

A few miles west of Mountain City small manganese deposits have been reported by the citizens.

In a cut for a race track in the fair grounds of Mountain City is exposed a 2-foot vein or bed of soft earthly manganese, standing almost vertical in yellowish clay, the residual material of the Watauga shale formation. Farther back on the foot of Forge Mountain, pieces of manganese float of harder varieties occur.

The following analysis was made by Dr. Paul C. Bowers, Chemist to this Survey, of the earthy manganese (probably *wad*) found at the Fair Grounds:

Analysis of earthy manganese, Fair Grounds, Mountain City.

Insoluble siliceous	18.16
Manganese (Mn)	35.10

*Weeks, J. D. Seventeenth Ann. Rept. U. S. Geol. Surv., pt. 3, 1896, pp. 202-203.

†Birkinbine, John, Mineral Resources U. S. for 1900, p. 124.

Digitized by Google

In Roane Creek Valley, south of Mountain City, through which passes the Virginia and Southwestern Railroad from Bristol, there are a number of small deposits of manganese. Only one of them has been given much attention. This deposit lies three-fourths of a mile southeast of Shouns on the side of a hill opposite what was formerly known as Jackson's store. The deposit has been prospected and some of the people of the county claim that a car load of the ore was shipped away. It lies on the Virginia Iron, Coal and Coke Company's property. The mineral occurs in the residual clay of the Watauga formation and scattered over the surface as float. It deserves attention and should be prospected by digging trenches running up-and-down the hill in the clay. The mineral is also associated with chert, occurring in the same residual mass.

Pieces of float manganese lie on other foothills in Roane Creek Valley. Such float material may be found near Maymead. Some of it is in chert breccia.

About a mile south of Neva, west of Mill Creek and Baker Gap postoffice, occur siliceous rocks on the surface of a high hill, which are filled with crystals of manganite. The geological horizon of this material is close to the contact of the Shady limestone and Erwin quartzite.

Fragments of manganese minerals are found in many of the iron ore pits, especially the ones formerly mined near Shouns.

North of Mountain City, in the foothills which are drained by Laurel Creek, are several small deposits of manganese and manganiferous minerals. Some manganese is associated with iron ore on land belonging to R. P. Donnelly and to Norman Wills, 3 or 4 miles northeast of Mountain City overlooking the Laurel road. Iron was once mined 3 or 4 miles southeast of Laurel Bloomery, on a branch of the Laurel Railway (narrow-guage), from the Ward Ore Bank, and with this ore is associated some manganese. Manganese float may be found along the foothills of the eastern side of Laurel Valley.

In the northeastern part of Johnson County, at the foot of Pond Mountain, near Matney, on Owens Branch, there is a deposit of manganese on land belonging to Mr. J. H. Reece. The deposit evidently occurs in the residual material of the Shady limestone formation, which is, in this region, very badly

Digitized by Google

disturbed through mountain-making forces. White actinolite schist and blue schistose rock are associated with the dolomite of the formation. This deposit was prospected some years ago, by a company, it is said, of Abingdon, Virginia. The manganese has much the same occurrence as that described at Jackson's store, and it is well worth further prospecting. At present the float ore is strewn all over the hillside. This deposit is within 3 miles of Taylors Valley, Virginia, which is on the Virginia-Carolina Railroad, and within 2½ miles of the Laurel Railway, at a point 3 miles from Damascus.

Anderson County.—A partial analysis of a specimen of ore sent in by Geo. C. Nettleton of Coal Creek, was made by Dr. Paul C. Bowers, Chemist of this Survey, with the following result:

Analysis of specimen from Coal Creek.

Insoluble siliceous material	15.33
Mn (metallic manganese)	43.95

This was a good specimen, but the writer knows nothing of the amount of the ore nor the geological relations under which it occurs.

Digitized by Google

Prehistoric Man in Tennessee

The co-operation of our readers is earnestly requested in aiding the movement put on foot by Mr. W. E. Myer, of Carthage, Tennessee, to gather information in regard to primitive man in Tennessee. Our State is exceedingly rich in mounds, graves and caverns. If man of the same age as cave man in Europe ever existed on this continent his remains will likely be found in our caverns. Many scientists believe cave man lived here.

Mr. Myer, in connection with Prof. Warren K. Moorehead of Peabody Museum, Andover, Massachusetts, is engaged in writing a much needed book on Primitive Man in Tennessee. This book will be a very large one and is intended to give a list of all our caverns, mounds, and graves of the Indians or other primitive men.

Our readers will greatly aid the advancement of scientific knowledge by writing to W. E. Myer, Carthage, Tennessee, and telling him about such caverns as they know, and stating whether they show signs of having been lived in or used as places of burial. Also, Mr. Myer would like information concerning mounds, whether or not they have been explored, and by whom explored, and whether they contain Indian graves. He will gratefully acknowledge in his forthcoming book the information thus sent in. This work will be of great scientific interest and has been long needed. Mr. Myer will refund the postage on any letters sent him in this connection.

Digitized by Google

UNIV. OF MICH. LIBRARY

VOLUME VI NUMBER 3

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY AND OCTOBER
BY THE
STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

JULY, 1916

CONTENTS

The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad.....L. C. Glenn
The Tennessee Coal Field South of the Tennessee Central Railroad.....Wilbur A. Nelson
Publications of the State Geological Survey.

Entered as second-class matter January 10, 1913, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

VOLUME VI NUMBER 3

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey
NASHVILLE, TENNESSEE

TN
24
.T2
A4

JULY, 1916

State Geological Commission

Gov. TOM C. RYE, *Chairman*

DR. BROWN AYRES, *Secretary*
President, University of Tennessee

H. KNOX BRYSON
Commissioner of Agriculture

DR. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

R. A. SHIRLETT
Chief Mine Inspector

Geological Corps

A. H. PURDUE
State Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

C. R. WATKINS, JR.
Traverseman

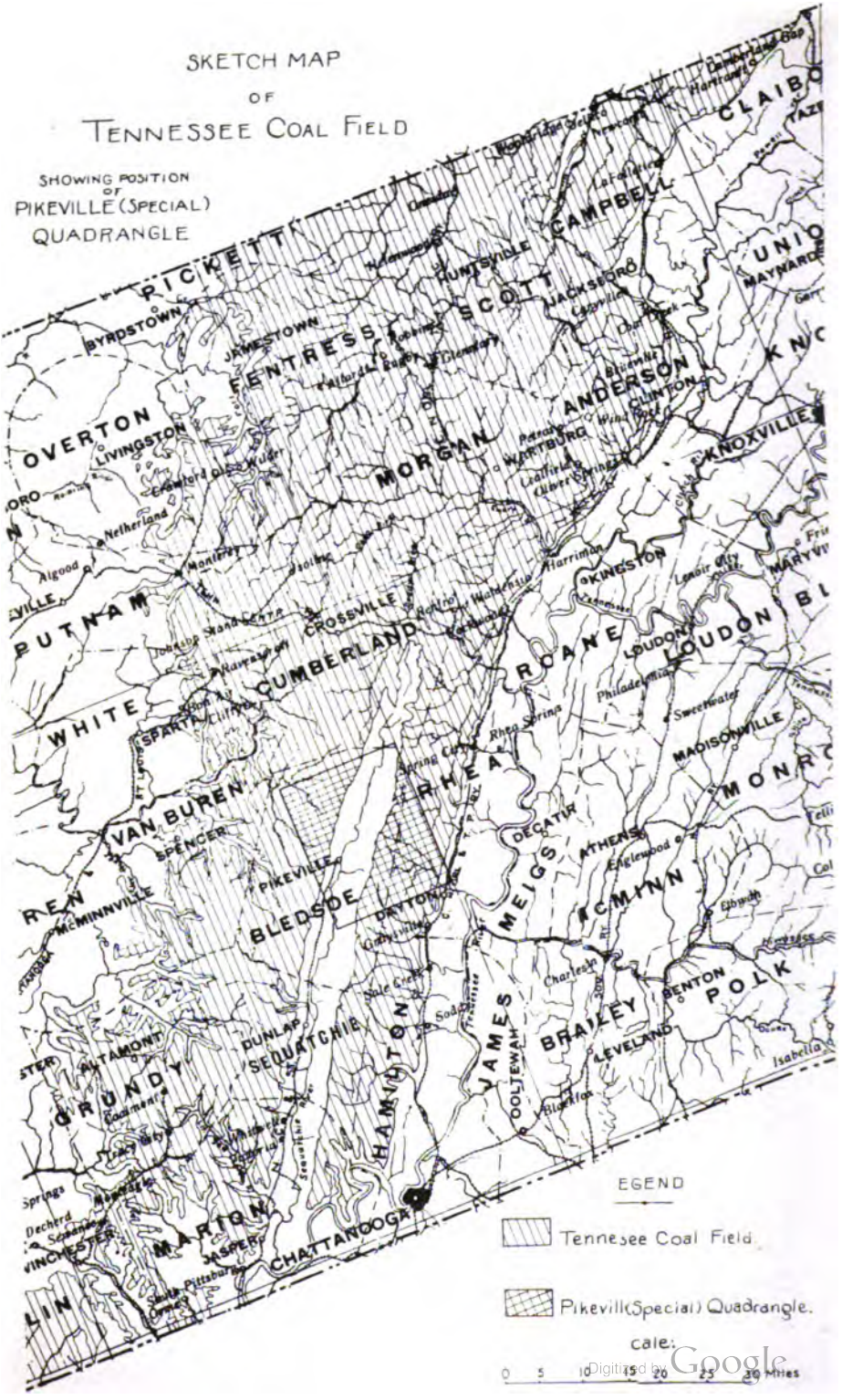
CONTENTS

The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad.....L. C. Glenn

The Tennessee Coal Field South of the Tennessee Central Railroad.....Wilbur A. Nelson

Publications of the State Geological Survey.

Digitized by Google



Digitized by Google

The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad*

BY L. C. GLENN.

Purpose and basis.—The purpose of the following preliminary report is to give a brief statement of the general facts now known as to that part of the coal area of the State, which lies north of the Tennessee Central Railroad. The report is based on a personal reconnaissance of the area made in 1911 and 1912, and is intended to give as much general information as is now possible in reply to the many inquiries received by the Survey as to the coals of this region. Necessarily, details are largely omitted and correlations of coals from area to area are touched upon lightly, since such work to be of certainty and value, can only be done in a region like this by careful detailed work. It is hoped that this reconnaissance may be followed by detailed studies of at least the more important parts of the region and that the results of these studies may be published in full detail.

*This paper and the succeeding one are revisions of the ones issued in Vol. III, No. 1, of the *Resources of Tennessee.* They are only general, preliminary statements of the geology of the Cumberland Plateau and the coal beds of the area. The demand for information on Tennessee coal has been so great that the first issue was exhausted several months ago. The fact that the demand still continues, and the further fact that it will be more than a year before a rather full report on the coal field of Tennessee now in preparation can appear, supplies the reason for republication.

In 1915, this Survey, in co-operation with the United States Geological Survey and the United States Bureau of Mines, collected and analyzed somewhat more than four hundred samples of Tennessee coal. These samples were taken from all parts of the Cumberland Plateau, the area in which the Tennessee coal occurs. The analyses contain a great deal of information supplementary to these articles and are published in Bulletin 621-P, United States Geological Survey, Washington, D. C. This can be had by applying to the Director.

A. H. P.

Digitized by Google

Divisions.—The area to be considered may conveniently be divided into an eastern and a western part by a line approximately coinciding with the Queen and Crescent railroad from Harriman northward to the Kentucky line. These two parts stand in contrast to each other in their topography and geology, and in their economic importance and industrial development, as will be shown in describing each area. When the entire coal-bearing area of the State is considered, the above divisions form the northwestern and northeastern parts, and may be so designated.

THE NORTHWESTERN COAL AREA.

This area lies, as has been said, north of the Tennessee Central and west of the Queen and Crescent railroads, and embraces parts of Pickett, Overton, Fentress, Putnam, Cumberland, Morgan and Scott counties.

Topographically, it is a broad plateau, with an average elevation of 1,200 to 2,000 feet. Its surface is level or gently rolling except along the larger streams, which flov in deep and narrow gorges, whose sides are formed in large part by cliffs of sandstone or conglomerate that in many places are 100 to 200 feet or more in height. These gorges may cut down entirely through the coal-bearing rocks and reveal the shales and limestones beneath, as for example, the gorge of Obey's River and of its principal tributaries. The western edge of the coal field is an escarpment of irregular outline that overlooks the Highland Rim some 400 to 600 feet beneath it.

The rocks of the northwestern area are mainly confined to the lowest or conglomerate division of the coal measures, though toward the eastern part of the area these rocks are overlaid by a thin covering of higher coal measure rocks that are usually cut through along the streams, revealing the lower rocks beneath.

These lower rocks consist of conglomerates, sandstones, and shales in very varying thickness and proportion. In fact the great characteristic of these rocks is their variability. At Monterey there are two beds of conglomerate but the lower one quickly changes to shale and disappears to the northward. Farther east there are several. To the northest in Fentress and in Pickett counties there may be either one or several beds

Digitized by Google

of conglomerate. This conglomerate may contain abundant well rounded pebbles or may rapidly change laterally or vertically into a sandstone which is often of pinkish color. It is soft and easily disintegrated, and gives rise to the sandy surface which characterizes nearly all of the plateau. The shales also vary in short distances from a few feet to a score or more in thickness, and the coals likewise partake of this variability as will be noted presently. The thickness of this conglomerate, or Lee formation, is 250 to 350 feet about Monterey, but eastward and northeastward it thickens until it becomes 500 or 600 feet thick near Rugby and in northwestern Scott County.

The structure is simple. The rocks lie measurably flat over large areas, though they have a gentle inclination to the eastward and disappear by passing beneath the higher rocks that make the surface of the area east of the Queen and Crescent Railroad. A slight anticlinal fold extends into the area from the southwest at Crossville, but soon flattens out and disappears. Eastward at Crab Orchard there is an anticlinal fold of greater magnitude and of more economic importance.

The economic significance of the structure and topography are at once apparent. The coals outcrop only along the western edge of the plateau and in the sides of the deeper gorges cut by the streams that drain the western side of the plateau. Back from this eroded edge of the escarpment and from the stream gorges, they are entirely concealed by the rocks that form the surface of the plateau, and can only be reached by drilling. Prospecting and development where there are outcrops above drainage will be by simple and inexpensive drifting, but back on the plateau prospecting can only be done by drilling, and development must be by shafts, the depth of which will vary from 150 to 400 or 500 feet, according to location, the greatest depth being where the conglomerate is thickest in eastern Pickett and Fentress, northern Morgan and western Scott counties. There the thickness of the conglomerate ranges from 500 to 600 or possibly 700 feet.

At Crab Orchad the anticlinal folding has exposed the entire thickness of these lower coal measure rocks, but the coals are so badly disturbed by the crushing and faulting incident to their upturning that all attempts to mine them along their out-

Digitized by Google

crop there, have so far failed. Away from their upturned outcrops they rapidly flatten out, and in a short distance, it would be entirely possible to reach them by shaft at a depth of one to three or four hundred feet, and the day is probably not far distant when this will be done.

Another result of the folding at Crab Orchard is that on the flank of the fold on the eastern side of the mountain a coal in the shales above the top of the conglomerate, and generally regarded as the equivalent of the Sewanee coal, has been crumpled and squeezed until it shows at Fall Creek and elsewhere near there a usual thickness of six to ten feet, and in places is 20, 30 or even, it is reported, 40 feet thick. This abnormal thickness is of course compensated for by a corresponding thinning elsewhere in the immediate vicinity. This thinning is usually at a point *higher* or *lower* on the flank of the anticline and not along on the same level, though pinching out at the same level may occur at infrequent intervals.

COALS.

The coals of the northwestern area are mined in comparatively few places, and there are very few country banks or natural exposures. In much of the region the coals are entirely below drainage over large areas, and are totally inaccessible except by drilling, and so far very little drilling has been done. Our knowledge of the coals of this section is therefore limited and may or may not approximate the conditions in the large areas where they are yet unexplored.

The characteristic of these conglomerate coals is their variability. Their thickness is rarely the same over any considerable area. In one mine it varies often materially from room to room, and it is not certain that any one bed is continuous for more than a few or a few score miles. It seems certain that the coals of the conglomerate were deposited in local basins and that while neighboring basins in some cases were contemporaneous in others they probably differed somewhat in age. This greatly complicates the problem of tracing and correlating the coals of the conglomerate.

The lowest coals rest in places almost on the Mississippian limestone, while in other places they are 25, 50 or more feet

Digitized by Google

above the limestone. A mile south of Cook Place, the old Murdock opening shows a hard, clean splint coal that varies from 18 to 20 inches in thickness in a drift 125 feet in length. The roof varies from a good sandy shale to a weak slickensided clay. At an opening in this same hollow and probably only a few yards away, but now covered up, Safford reported this coal to be four feet thick. It seems to be of excellent quality, and would be quite valuable if on investigation it proved to average as much as three or three and a half feet over an area large enough to mine. Practically no prospecting has been done in the vicinity, and its extent and average thickness are unknown. It is about 55 feet above the limestone.

At Wilder, some five or six miles to the southeast, two thin rashy coals 10 to 12 feet apart occur at about the horizon of the Murdock coal some 75 or 80 feet above the limestone. Sixty-five feet higher the Wilder coal occurs. It is actively mined at Wilder, where it averages three and a half to four and a half feet in thickness, though it occasionally runs higher or lower than these measurements. It has no parting, but separates naturally into an upper, middle and lower bench, the lower being the highest grade, and the middle carrying some sulphur in balls or thin streaks. A mile and a half away the Overton Coal and Coke Company mine the same coal. It varies there from four and a half to six feet in thickness, with an average of about five feet, and is without partings. The same coal is mined at Crawford, where it averages three to three and a half feet in thickness, but varies considerably from this by thickening in sags in the floor and thinning in crossing intervening ridges. These sags run as a series of parallel troughs with a general northeast-southwest direction, and vary in width from a few to 1,200 feet each. On the ridge between adjacent troughs the coal may thin to 15 inches for a few feet or yards. The roof and floor are generally good.

Six miles south of Crawford a coal is mined at Obey City that is probably the same as the Wilder coal. It is in about the same stratigraphic position, and is similar in general character, though it probably carries somewhat more sulphur. It averages 34 to 40 inches in thickness and does not vary greatly from these limits.

Digitized by Google

North of Wilder a coal is known in several places on the tributaries of the East Fork of Obey River that is believed to be the Wilder coal, and it may be the same as the coal seen by the writer in Buffalo Cove at two places and measuring 54 and 56 inches respectively. The doubt in correlation arises from the fact that this coal is very close above the limestone while the coal at Wilder is 130 to 150 feet above the limestone. The two coals may nevertheless prove the same, the discrepancy in the distance down to the limestone being due to irregularities in the surface on which the coal measures began to be deposited.

Farther north in Poplar Cove a coal averaging three to three and a half feet, and worked for use in Jamestown, occupies about the horizon of the Buffalo Cove coal while farther northwest some six or eight miles a coal was formerly mined extensively for local use at several places on the ridge on either side of Crickett Creek. The workings were all fallen in when visited, but it was reported to be four and a half or five feet in thickness, and on the Smith place west of the creek this thickness must have been substantially correct. The quality seems to have been good, and it was free from partings, and seems to have a good roof.

East and northeast of Buffalo Cove, a number of drill holes have been put down. The earlier of these were with a churn drill, while the later were by core drill. They are grouped mainly within a radius of four or five miles of Allardt, though there is another small group on Clear Fork some eight or ten miles to the southeast. The writer has the logs of only a few of these wells. Of some of the others he has merely a statement of the thickness of the coal without exact information as to its depth, or as to the elevation of the well mouths. It is accordingly difficult to make as exact statement as is desirable as to the coals of the region. Coal is apparently thin or absent in churn holes, 1 and 3, in and three-fourths of a mile west of Allardt respectively, and in 4, some three miles northwest, and 5, about the same distance southwest of Allardt. In diamond drill hole D very near hole 5, the coal is three feet thick; in F two miles south of Allardt it is five and a half feet thick; in E near the mouth of Barn Creek four miles southeast of Allardt it is five feet thick; while other churn and core records at five

Digitized by Google

points from one to three miles east of Allardt show the coal to be three, four and a half, five and five and a half feet respectively.

Three churn holes on Clear Fork some eight miles southeast of Allardt show four and a half feet of coal each.

From what can be gathered as to elevation it seems very probable that these records are all of the same coal, and that this coal is certainly the same as the Buffalo Cove coal, and probably identical with the Wilder coal. This coal shows an average of about four feet with a few places where it is thin or absent. From the wide distribution of the holes, it seems that there is a large body of coal three to five and a half feet thick in that region, that may be reached from the plateau level at a depth of 250 feet near the Buffalo Cove edge of the plateau or of 350 feet some six or eight miles to the east, or may be reached in the valleys of Crooked Creek and other streams at 150 feet or less, dependent on location.

On the headwaters of Wolf River the coal appears to be thin. Several exposures show two or two and a half feet as the maximum thickness, though considerable areas have never been prospected.

To the northeast of Allardt and Jamestown the plateau level is not cut deeply enough by streams to reveal this coal until the Stearns mines in Kentucky, some 25 miles away are reached. There several coals quite regularly four to five feet in thickness and of excellent quality, are mined. Two of these coals are only a few feet apart and very close above the limestone, the other known as the Barthell coal is some 40 to 60 feet higher. This latter coal may represent the Allardt coal, and if so, it would seem probable that the drill would show the Pickett and Fentress county region between these places to contain the same coal.

The logs of the Forest Oil Company's wells near Rugby show little or no coal in that region, and near Bledsoe's Stand, churn drill holes sunk some twenty or thirty years ago report no coal.

In very few of the oil wells recently drilled in and northwest and west of Oneida, was there any coal found.

At Isoline there is a coal locally thick enough to be of commercial importance, that seems to lie at a higher horizon than

Digitized by Google

the coals that have been described. It is only a few feet beneath the 60- to 100-foot bed of soft conglomerate that makes the plateau surface over large areas there and elsewhere. The coal lies in a trough 600 to 1,200 feet wide and is known to extend westward for two and a half miles, where it is five feet thick. What its farther extension is in that direction is not known. It runs from two and a half to five feet in thickness, and showed the following section:

Shale roof	Inches
Coal	2½
Bone	2½
Coal	2
Bone	2½
Coal, bituminous	37
Coal, cannel	3
Under clay, soft	12

The coal is bright, fairly hard, lumps well and seemed free from sulphur balls and streaks.

No coals are opened or mined in the northern part of Cumberland County, except at Isoline. In the northeastern part of the county on Obed River at the mouth of Elmore Creek, an oil well recently drilled reports a coal over five and a half feet thick at a depth of 134 feet. This may be about the horizon of the Wilder and Crawford coal.

Just west of Crab Orchard Station, on the Tennessee Central, and again in Crab Orchard Mountain just east of the station, the conglomerate is upturned and its entire thickness exposed to view. Attempts have been made in both places to mine the coal exposed in it, but it was found too badly crushed and disturbed to make the venture a success.

Just above the conglomerate on the east side of Crab Orchard Mountain, at Fall, Millstone and Mammy's creeks, the Rockwood coal has been mined where it has been thickened up to 10, 20 or exceptionally 40 feet in lenticular pockets. The pockety nature of the coal has made its mining very uncertain. The first of the above mines was being robbed preparatory to abandonment, the second was in litigation and closed, and the third had been abandoned when visited. It seems very probable that a little farther east from these mines there are a good number of square miles of territory in the middle of the broad flat-bot-

Digitized by Google

tomed syncline between the Crab Orchard and the Cumberland mountains where this Rockwood coal will be found by drilling to be of good thickness and free from disturbance. So far as is known this region has not been explored with the drill. The Rockwood mines, however, have been operating for years on the eastern margin of the same coal and have workings that are now some two miles back from the mine mouth. The coal is about four feet in thickness and is coked and used at Rockwood in making iron. There is undoubtedly a large area in this section where careful prospecting would reveal coal thick enough and regular enough in its thickness to make it commercially practicable to mine it on as large a scale as might be desired.

The quality of the conglomerate coals would not be as high as the Coal Creek or some of the other coals of the northeastern section. This would not make much difference from a commercial standpoint, however, since these northwestern coals would not naturally find their market in the territory of the coals on the east of them but would be shipped westward into middle and western Tennessee and Kentucky, where they would compare favorably in quality with the coals from western Kentucky with which they would come into competition, and ought to be able easily to hold their own in competition with any of these latter coals.

Before they can be developed to any great extent it will be necessary to construct railways into the region. Much of it is 40 or 50 miles from transportation at present, and must remain undeveloped as long as the present lack of transportation continues.

It is true that in early days some coal in Fentress and Pickett counties was floated on barges down the Obey and Cumberland rivers to Nashville, but the price of coal in Nashville today is only a half to a third of what it then was and rafting coal is no longer practicable. Railroad building on the plateau would be easy and inexpensive, and almost any point could be reached without difficulty.

The conglomerate coals vary enough in thickness and are locally absent over small areas often enough to make it necessary to prospect any given property very thoroughly with a diamond

Digitized by Google

drill before making purchase or attempting development. It seems from all of the evidence available, that the coals are more irregular and pockety in the region about Monterey, where an attempt to mine them failed because of the very pockety character of the seam, and to the east and southeast, and that they become more persistent to the northeast and will probably be found, when prospected, in northern Fentress and middle and eastern Pickett counties to be more nearly like the Stearns coals in their thickness, regularity, and quality. By observing merely such precautions as would be obviously desirable in undertaking any plan for mining development anywhere, there is no reason why this territory may not be developed so as to yield as large a tonnage as may be desired.

Above the conglomerate the only coals of value in this northwestern section would seem to be the ones in its southeastern and northeastern corners. In the synclinal basin between the Crab Orchard anticline and the Cumberland escarpment, the occurrence of the Rockwood coal has been mentioned. It probably extends northeastward into the basins of Crab Orchard and Clifty creeks, but has received no development and probably has not even been prospected.

The rocks of this northwestern area dip gently eastward, and near the eastern edge of the area pass beneath the shales and sandstones that make the surface rocks of the northeastern distinct. At a number of places these higher rocks extend westward across the Queen and Crescent Railroad, especially from Sunbright northward to the Kentucky line. From near Oneida northward these higher rocks west of the railroad contain a coal that is mined at Bear Creek and is also mined at a number of places east of the railroad, as for instance at Glen Mary, Robbins, Almy, LeMoyne and elsewhere. At Bear Creek, the Virginia Mining Company's opening showed the following section at the head of the main entry and of the first and third right entries:

Shale roof	Main Inches	1st right Inches	3d right Inches
Coal	7	8½	7
Splinty bone	1	½	1
Coal	6½	6	6½
Bone	5	10	5½
Coal	20	18	19

Digitized by Google

This Bear Creek coal traces southwestward to Paint Rock at Almy and eastward to the LeMoyne mine on Gum Fork of Jellico Creek and farther tracing eastward makes it very probably the same as the Dixie coal at Newcomb and Jellico.

In summary it may be said of this northwestern coal field that it is very imperfectly known, largely because of the fact that except along its eroded western edge its coals generally lie several hundred feet beneath the plateau surface and are more expensive to prospect than where they crop at the surface. The conglomerate coals so far developed are relatively high in ash and sulphur and are not coked, but are used exclusively as steam and domestic coals. They are marketed along the line of the Tennessee Central Railroad, a large part going to Nashville, and some is shipped through Nashville to points on other railways in competition with coal from West Kentucky. Little or none goes east beyond the end of the Tennessee Central since it then comes into competition with the near-by coals on the Southern and Louisville and Nashville railroads in the northeastern section of the field next to be described.

The Bear Creek coal finds its market on the Queen and Crescent road either for use by that road or for steam and domestic use northward in Kentucky or southward toward Chattanooga. Under certain market conditions, especially when strikes prevail in the West Virginia or the Illinois-Indiana region, this coal finds a market north of the Ohio River.

THE NORTHEASTERN COAL FIELD.

This field embraces the coal-bearing area of Tennessee lying east of the Queen and Crescent Railway. It is roughly triangular and is bounded on the north by Kentucky, on the west by the railway just mentioned and on the southeast by the somewhat irregular but sharply defined line made by the Cumberland Mountain escarpment extending from Harriman to Cumberland Gap. It is the most important coal-producing area in the State.

Topographically it stands in sharp contrast to the northwestern region just described. Instead of being a plateau with a broadly flat or rolling surface beneath which narrow stream gorges here and there are cut, it is a maze of sharp crested

Digitized by Google

ridges winding and branching in the most intricate fashion and separated from each other by deep and usually narrow V-shaped valleys, cut by the many-branching streams of the region. Many of the ridge crests rise to 3,000 and some even to 3,500 feet in height. In most places the ridge crests are sharply rounded, and some of these have good soils and are cleared, while in other places the crests are cliff-capped and wild. The sides are generally very steep except where some heavy sandstone here or there stands out in a line, it may be, of bold clifts and holds just above it a gently sloping bench that contours the mountains possibly for miles. These benches are cleared and farmed in many places, but the steep slopes are usually heavily wooded. Roads are confined mostly to the stream valleys. Few of them cross the ridges, and many a mountaineer's cabin, perched high on a bench or on some ridge crest, may be reached only by a narrow, steep bridle trail.

The deep dissection of the rocks of this northeastern region has removed much of the coal it once contained, since many of the thickest coals are found on the middle or upper slopes of the ridges where they are comparatively narrow, and where the area that has been removed by erosion is a number of times greater than that left in the ridges that remain.

While there has been such economic loss from erosion there has also been much economic gain since the deep dissection has laid bare some low-lying coals of great extent and value, as for instance the Coal Creek and Jellico coals, and at the same time has rendered the coals of the entire region much more easily prospected than are the coals of the plateau region.

Where the coals crop from the mountain side as those in this region do over most of their extent, it is so easy to open them by drift that when a coal goes under drainage level no effort is made to reach it by shaft. In many places a shaft mine would not be more expensive to open, operate and maintain, down say to the Coal Creek coal after it has gone under drainage level, than are some of the long, steep inclines used to reach the coals high on the mountain sides where the area of coal is probably small and the life of the mine correspondingly short as compared with a shaft mine, where the entire area about the mine contains coal. There are no shaft mines in the district,

Digitized by Google

the nearest approach to such being the slopes by which the Rex coal is reached at LaFollette.

The geology also of this northeastern division is in direct contrast to the northwestern. Instead of one formation a few hundred feet thick in which sandstone and conglomerates predominate, we have here a number of different formations aggregating 2,000 to 3,000 feet in thickness in which shales predominate. Instead of having one, two or three coals as in the conglomerate we have here a dozen or two of coals, quite a number of which are at one place or another of commercial

Coke ovens, LaFollette, Tenn.

thickness and value. In addition to these coals above the conglomerate and accessible over most of this region above drainage, the conglomerate itself also extends under all of this region and doubtless contains coals of value that will some day be reached by shaft, as the top of the conglomerate lies only a few to a few hundred feet beneath drainage level in much of this northeastern section.

The rocks above the conglomerate have been divided by the U. S. Geological Survey into a number of formations, but in the present brief description it will not be necessary to describe these formations or give their areal extent. The folios in which

Digitized by Google

they are described and mapped may either be obtained in Washington or are accessible in many libraries.

In structure this division is not quite so simple as the northwestern one. Its eastern and southeastern edge is delimited by the Cumberland escarpment where the coal-bearing rocks rise rapidly into the air to the southeast along a line usually of faulting with an overthrust from the northwest. This line extends from Cumberland Gap almost straight southwestward to near Careyville and there curves to the southeast to Coal Creek beyond which it soon resumes its usual southwest course and under the name of Walden Ridge extends to Harriman and beyond.

Ten miles northwest of and parallel to the Cumberland Mountains there is the Pine Mountain fault. It extends from near Jellico southwest to Pioneer, where it turns sharply to the southeast and becomes a cross fault that joins the Cumberland Mountain fault near Careyville. The overthrust here is from the northeast and the ridge made by the conglomerate is known as Fork Mountain.

This Pine Mountain fault is overthrust from the east and the upturned conglomerate forms the crest of the long rugged Pine Mountain ridge, just as it does the parallel crest of the Cumberland to the southeast. The basin enclosed between the Cumberland, the Fork and the Pine mountains is thus separated structurally from the rest of this northeastern field. It is drained almost entirely by Clear Creek, and may be called the Clear Creek basin. In this Clear Creek basin the steep inward dips on either side quickly die away, especially on the Cumberland Mountain side, and in a few hundred feet the rocks become flat. Such abrupt flattening is indeed, characteristic of both the Cumberland and Walden Ridge, at least as far south as Rockwood.

The remainder of the northeastern coal field is a very broad shallow basin with very gentle dips. Much the larger part is drained by New River, which flows approximately along the axis of this basin. It is probable that the syncline has a northern branch that parallels Pine Mountain and is occupied by Jellico Creek. Dips in all cases are gentle except for local

Digitized by Google

minor folding such as may be seen on Brimstone Creek near the mouth of Hutson branch.

The Clear Creek basin between the Pine and Cumberland mountains may be considered as a unit. It is crossed diagonally by the Louisville and Nashville Railroad, and a branch of the Southern extends up Clear Fork to the Kentucky line. Numerous mines are operated on these lines of road and the relation to each other of the coals now developed is reasonably clear.

The lowest coal mined in the basin is the Rex. It is about 300 feet above the Lee conglomerate and is doubtless equivalent to the Coal Creek coal which it resembles in various ways.* It is mined at LaFollette. The roof is slate that where undisturbed may hold very well, but which falls readily when shot down along entries. About a foot from the top the coal generally has a parting that varies from 0 to 12 inches with an average of about 2 inches, while the coal beneath it averages two feet. This coal is low in ash and sulphur, and is coked for the furnace at LaFollette. Above it at LaFollette 513 feet is a coal locally known as the Kent. This coal was formerly worked immediately above Rex mine Number 2. The section varied much in different parts of the mine. The top coal varied from 5 to 25 inches, then came a dirt band from 1 to 18 inches beneath which the bottom coal varied from 18 to 26 inches. It was high in sulphur and ash. It seems very probable that it is the equivalent of the Jellico coal.

At the Gem mine some seven miles north of LaFollette on the ridge between the head of Lick and Rocky creeks a seam locally known as the Jordan, is worked. It is reported to be 1,200 feet above the Rex coal there, which was supposed to be reached in a bore hole at a depth of 620 feet. Two small coals regarded as the Kent, there split, are found 500 feet beneath the Jordan, which has an elevation above sea of 1987 feet at the mine mouth. It dips gently northwestward and varies but little from 48 inches of coal with a parting usually about a foot from the top that varies from one to six inches. This parting may be rash, or clay, and either free from or mixed

*Evidence is accumulating that the Rex coal is lower or older than the Coal Creek coal, and that the Coal Creek and Kent are the same.

Digitized by Google

with coal. The area, owing to the elevation, is limited, but two or three miles to the northeast it is mined at Cotula, where it has very similar section and thickness, except that the parting varies from zero to four inches, and part of the coal runs up to five feet or occasionally more in thickness.

In the section along the Louisville and Nashville Railroad from Cotula north to Chasca the lowest seam exposed is the Kent.* It is split into two benches the lower of which has been mined at several places generally under the name of the Italy seam. It averages 34 inches and has a sandstone roof and hard shale floor that make working expensive. At Cotula, it is below railway grade, but near Chasca it begins to rise rapidly to the northwest under the influence of the Pine Mountain fault.

About 220 to 290 feet above the Kent or Italy seam along this section of Davis Creek is the Rich Mountain seam mined at Wynn, Remy, Rich Mountain, Cupp, Kimberly and Chasca. It has an average thickness that varies in different mines from 30 to 44 inches and may or may not have a thin clay parting of rash beneath it. It is probably the Blue Gem coal.

Some 90 to 125 feet above the Rich Mountain coal on Davis Creek is the Log Mountain seam. This seam is mined only at Jackson and Westbourne, where it averages about 44 inches and is solid. Elsewhere it seems to be split or thin in this section in the few places where search has been made for it. In the western part of each of the above mines the upper 10 inches is cannel. In the eastern workings this cannel disappears.

This Log Mountain or Westbourne coal is the same as the Pruden and Mingo and is believed to be the same as Jellico, the Twin seam of the Briceville region and the Petros or State seam. The area above this horizon in the ridges in the Clear Creek basin is in the aggregate large and further prospecting will doubtless disclose other areas where it is of workable thickness as it is a coal of widespread occurrence both in Kentucky and in Tennessee.

About 150 feet above the Log Mountain coal is the Jordan which, as has been seen, is mined at the Gem mine at Peabody,

*The Kent is probably not the same as the Jellico but older. The Kent and the Little Italy, the Anchor, Anthras, Egan and King's Mountain coals are believed to be the same.

Digitized by Google

and at the Southern Coal & Coke Company's mine at Cotula. It is probably the same as the Splint coal at Elk Valley and is close below the Lower Pioneer coal. About 100 or 125 feet above the Poplar Lick coal in the Middlesboro region is the Klondike or McGuire coal, which carries marine fossils. In the Coal Creek and New River region a coal known as the Big Mary is also characterized by the marine fossils it carries, and is associated with other coals above it, one of which is usually correlated with the Dean. It is probable that the marine fossils characterize the same coal, and if so the Dean could not be below it in one region and above it in another. This tangle of correlation can only be worked out by future detailed work.

At Morley, two mines work a coal that is locally called the Kramor seam. It is 32 to 35 inches thick, is reported to be about 250 feet above the top of the conglomerate and is probably to be correlated with the Kent seam of the LaFollette region.

On Clear Fork at Anthras and Clairfield several mines operate on a coal generally considered to be the Jellico, but that is more probably the equivalent of the Kent, the Jellico being represented by the Pruden coal some 420 feet higher at Clairfield. It varies much in thickness in the mines and prospect openings that have been made. Where mined it averages from 42 to 52 inches and may be solid or may have a parting that varies up to 12 inches in thickness, but is frequently absent. In a prospect on Rock Creek, the thickness is reported as 68 inches. There is a large area to the south of Clear Fork in which this coal occurs, though its thickness there is not known.

Near the head of Clear Fork at Pruden and at Fonde a coal some five or six feet in thickness is extensively mined. It is usually split into three benches by two clay partings and in a portion of the area the upper parting is so thick that only the two lower benches of coal are mined while in other portions the upper parting is thin and the lower so thick that the middle and upper benches of the coal are alone removed.

In some places it splits into four or five benches of coal, but generally some two are large enough and near enough together to be worked. This coal is the same as the Mingo coal of Bennett Fork and is the same as the Log Mountain, the Westbourne

Digitized by Google

and the Jellico coal. At Clairfield it is 420 feet above the coal there mined.

In the Clear Creek basin spur tracks from the Louisville and Nashville or the Southern might easily be extended up any one of the numerous tributary streams and thus develop much new territory now untouched.

The discussion of the remaining portion of this northeastern coal field can best be undertaken by districts, beginning at Jellico and going southward and westward around the margin of the basin. This description may be relatively brief since many of the largest mines are on one or the other of a very few seams, such as the Coal Creek and the Jellico.

At Jellico the lowest coal known locally is the Swamp Angel. It is found at or a short distance below drainage level and is reported to be 32 to 34 inches in thickness. It is not mined. About 100 feet above it is another unmined coal known as the Dixie. It may be solid or split by a clay parting and is said to be 24 to 36 inches thick. Either this or the Swamp Angel is at about the horizon of the Coal Creek coal. This Dixie coal, when traced westward, correlates with the coal mined at the LeMoyne mine on Gum Fork of Jellico Creek. At LeMoyne there is a main bench of 30 to 33 inches above which there is a parting that is left as the roof. Above this parting, which varies from 8 to 36 inches, there are five inches of poor bony coal that is not mined.* About 100 to 120 feet above the Dixie there is a thin coal near Newcomb, known as the Black Wax, and some 60 or 70 feet above it is the Blue Gem coal. This latter coal is always thin, but is of such excellent quality as a domestic fuel that a thickness of 18 to 22 inches is mined in numerous places about Jellico. It is also mined at Elk Valley, where it varies from 16 to 24 inches.

About Jellico the Jellico coal is 90 to 110 feet above the Blue Gem. It varies greatly in thickness and in details of section within short distances. In one mine it varies from two to six feet. It may be solid, but more frequently has one or two partings, which vary in thickness, and in position, but which rarely

*This is the same as the coal at Almy, Bear Creek, Huntsville, Helenwood and Robbins and Glen Mary.

Digitized by Google

prevent the coal from being mined. It is mined at Jellico, Newcomb and Elk Valley.

Four hundred and forty feet by aneroid above the Jellico coal at Newcomb, there is an excellent cannel mined by the Zcheni Coal Company. It shows a top bench of 24 to 26 inches of cannel, one to two inches of parting and 8 to 11 inches of cannel, and is known to underlie a considerable area in thickness great enough to mine. Some other coals are known to occur above and below this cannel, but they have not been prospected sufficiently to determine their thickness or value.

It is underlaid by a flint clay that is of widespread occurrence and an excellent horizon marker.

At Pioneer, two coals were formerly mined that are known as the Upper and Lower Pioneer. These are relatively high in the stratigraphic section, but no attempt will here be made to correlate them with other coals. Neither is worked at present and but little information could be secured as to their thickness or character. They lie well below the tops of the ridges about Pioneer, and large areas to the northwest, west and south of Pioneer rise above their horizon. What their extent and thickness throughout this territory may be is not known.

Three miles south of Pioneer a spur track passes east through the gap in Fork Mountain and reaches the Rector mine, which was opened on what appears to be the Kent seam. When driven in about a thousand feet, the coal was cut off by a fault and the mine was abandoned. Some three miles east of there on the head of Ollice Creek, the same coal occurs. In each place it is four feet thick. This coal is also known at several points on Stinking Creek north of Walnut Mountain, so that it underlies much the larger part of the Clear Creek basin from Fork Mountain northeast to the Louisville and Nashville Railroad. We have already noted its development along that railroad, where it is usually known as the Italy coal, and its development also at Anthras and elsewhere on Clear Fork, where it is incorrectly known as the Jellico.

By a little geological work at Rector at the proper time the continuation of the seam beyond the fault could have been located and the mine might have been saved to its owners.

Digitized by Google

At Turley, Block, Red Ash and Careyville, there are a number of mines that work one or the other of two coals, situated near the tops of the mountain ridges. The strata rise considerably to the southward so that each coal is carried higher in that direction. Their general elevation where mined may, however, be taken as 2,300 to 2,750 feet above sea level. They are reached by inclines one to two miles long that have a vertical rise in that distance of 1,000 to 1,400 feet. The coal is lowered by gravity in monitor cars holding 10 to 12 tons each. The ridges at the horizon of these coals are relatively narrow so that individual bodies of coal readily worked from one opening average 400 to 800 acres.

The higher of the two ridge coals mined at the above places is locally known as the Rock Spring coal. It is mined at Turley and at Block, and is known to occur for some miles along the ridges and high spurs on the north side of the Montgomery Fork basin. By its rise to the southward it is carried up so near the tops of the ridges in that direction that it is doubtful if there are any considerable areas of it left there. Its exact extent, however, like that, indeed, of all of the other coals of the region is not known and can only be ascertained by detailed work.

A section of this is as follows:

	Inches
Coal	19
Bone	4
Coal	33
Clay	3
Coal	13

In some places the bottom bench of coal is absent or is bone and rash, and the bone between the two upper benches in places disappears, leaving a solid bench of 40 to 42 inches. The coal is hard and carries some sulphur in the bench above the bone. This bone is inclined to stick to the coal when present. Mining is either by machine or by shooting on the solid.

At Block 325 feet by aneroid below the Rock Spring coal another coal occurs that averages three feet in thickness. It is known as the Red Ash, and is mined at Block and is generally believed to be the coal mined at Red Ash, Careyville and the Sun mine. At Red Ash this coal has a top bench of 38 inches,

Digitized by Google

then, clay two inches and coal one and a half inches. At Careyville the coal is solid and averages 46 to 48 inches, and seems quite regular. At the Sun, it varies from three and a half to five feet in thickness, and on the right workings is solid, but on the left a soft clay appears slightly below the middle and had run up to eight inches when further work in that direction was stopped. It is not yet certain to the writer that these are all the same coal, though the Careyville and Red Ash mines are on the same seam.

At Block the Big Mary coal, there about 200 feet below the Red Ash or Block coal, was formerly mined extensively. It varied so greatly in detail of section and carried so much parting that it was finally abandoned. This coal carries marine fossils in its roof, and with the flint clay coal some 40 to 80 feet below it forms the best key horizon in the entire section.

The next mining region south of Careyville is Coal Creek, with which Briceville is included. The Coal Creek seam has been mined here for years on an extensive scale. The coal crops close above drainage for some 8 or 10 miles along Coal Creek and Valley Fork. It averages in the various mines 40 to 48 inches in thickness, with 42 inches as a general average, but varies greatly in detail in any one mine. Where of average thickness it perhaps more often has a knife edge to 4-inch parting than not. This parting is usually slightly below the middle. In some places the coal runs up to six feet locally and in a small mine just north of Briceville it is even thicker. The roof varies from a good sandy shale to a soft clay from place to place in the same mine, and when of clay requires much timbering and care to hold until worked. The top six to eight inches of the floor is a clay that softens when wet. The mines on this coal are usually dry and sprinkling is often necessary.

Near the crop this coal dips westward as much as 8 to 12 per cent. in places, but soon flattens out and over large areas has scarcely any dip. Some of the workings extend two miles into the mountain. Northward from Coal Creek its outcrop is soon concealed by the great Walden Ridge fault line except for a short distance near Careyville where it is mined by the Bear Wallow Company. In the Biceville-Coal Creek region this is

Digitized by Google

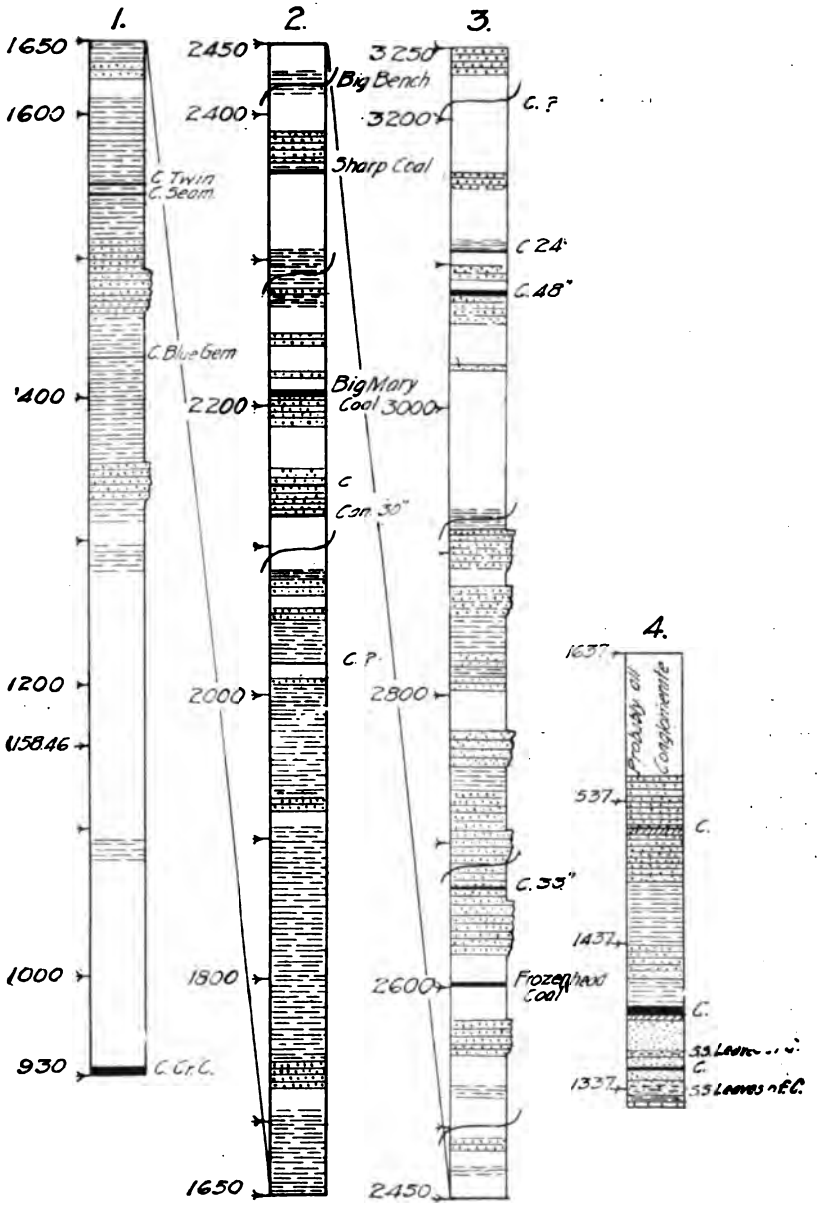
the only coal mined and until very recently no others had even been prospected to any extent.

Just recently some active prospecting has been done by Mr. L. J. A. Petrie on the mountain side west of the Black Diamond mine. Here he has faced a number of coals whose position and thickness are given on the long vertical section given herewith. These facings show that there are several promising coals well toward the top of the ridge, but still low enough to give a very considerable acreage. Similar work had been begun by Mr. E. F. Buffat on a spur of Cross Mountain west of Briceville, when this region was visited by the writer. It is evident that there are several promising coals in Cross Mountain some 1,200 to 1,600 feet above the valley floor to the east and some of them undoubtedly correspond to the coals mined some miles to the north from Careyville to Turley.

Southwestward from Coal Creek the next mining center is the Oliver Springs region. Oliver Springs bears much the same topographic and structural relation to the coal-bearing area that Coal Creek does. The coal there mined, often called the Poplar Creek coal, has generally been correlated with the Coal Creek coal. It is now known to lie 160 to 180 feet below the Coal Creek coal in the Oliver Springs region. This Oliver Springs or Poplar Creek coal outcrops at a number of places on Poplar Creek, Big and Little Cow creeks, and westward on the head of little Emory River north of Coalfield. It has been mined at numerous places in this Oliver Springs district in the past and is now mined at Big Mountain and elsewhere on Indian Creek, and in the vicinity of Coalfield. It lies only a short distance above drainage, in most places. Its average thickness is about 48 inches and it may be with or without a parting and the roof may be either a shale or a soft clay. Beneath it there is always clay. This coal is not definitely known northward on the New River basin. It is probable that it is one of several small coals that rise above water level near the mouth of Bull Creek a few miles below Norma.

Some 1,300 to 1,400 feet above the Oliver Springs coal there is a seam that is extensively mined at Windrock, where it is considered to be the Lower Dean. It averages 54 inches in thickness, but varies much in detail. In a part of the mine the coal

Digitized by Google



Sec. 1-2-3. Vertical section from the Black Diamond mine westward up Cross Mountain.

Sec. 4. Churn and diamond drill record D near Allardt.

Digitized by Google

is solid while in another part a thin band appears that thickens as shown by the drill, to 35 or 40 feet and then thins away again in no great distance to a few inches. Splits are of frequent occurrence in many of the coals of this northeastern region, and while rarely known to be anything like as large as the above one, they serve to puzzle the prospector and increase the difficulty and expense of operation. This is the horizon of the flint fire clay. It is 60 feet at Windrock below the Big Mary horizon.

This Windrock coal is very soft and friable and is sold almost exclusively as a steam coal.

Northwest of Coalfield the Oliver Springs coal soon goes under drainage and on the upper slopes of Little Brushy Mountain at an elevation of 1,700 feet, the State or Brushy Mountain seam some 600 feet above the Oliver Springs seam, appears and is worked by the Little Brushy Coal Company. Its average thickness there is 34 inches, and it is without parting. Northward at Petros, it is mined by the Big Brushy Company and by the State.

It varies much in thickness, but averages some 40 to 44 inches. It may be free from partings or one or more may be present either of rash or of clay. These partings are frequently in lenses only two to five feet across, or they may be persistent for some distance. The roof is generally a good shale, the floor is a clay. This seam is driven through to daylight on the New River side, but it has not been prospected beyond a mile or two north of its crop. It is a soft coal, cokes well and goes as coke to the iron furnaces chiefly at Dayton and Chattanooga, or is sold to the steam trade.

Attempts were made a few years ago by the State to mine a seam some 750 feet above the State seam, generally known as the Frozenhead seam, and correlated by some with the Upper Pioneer. The coal thinned to some three feet or less when the mine had been driven in some 2,500 feet and the mine was abandoned. A 32-inch coal 130 feet below the Frozenhead was opened and driven some 30 feet. It is solid and apparently good and clean. A hundred feet lower is another coal once opened but reported as badly split.

Digitized by Google

In the New River basin very little prospecting has been done and almost no mining. On Straight Fork of Smoky Creek the Big Mary coal was opened and mined for a short time by the Baker company. Where measured it has a main bench of 37½ inches above which were several thin alternations of coal, bone and partings. As usual it carries marine shells in the roof. The attempt to mine this coal was soon abandoned partly because of local freight rates and partly because of the unsatisfactory character of the seam. The Big Mary seam is everywhere very variable and unreliable, although it often presents locally a very attractive appearance. This coal has been faced on the head of Brimstone Creek of Smoky Creek where the only bench of consequence is a bottom one of 27½ inches. Two hundred and fifty feet higher another coal 50 to 52 inches and solid has been faced and 60 feet still higher there is a 38-inch solid facing. The 52-inch coal is a good-looking clean, hard coal.

Some prospecting has recently been done in the upper part of the New River basin that shows the Big Mary coal to be more promising in thickness and regularity than in the Block region. It is probable that considerable areas of it might be mined successfully in that region.

On Round Knob some eight miles southwest of Norma, at an elevation of some 2,000 feet there is a solid 64-inch coal on the Tom Jones place. A five-inch band of splint coal separates the bottom 12 inches from the top 47 inches. The coal looks good and clean. It is underlaid by flint clay and is at the horizon of the Windrock coal.

Just westward from Round Knob on Brimstone Creek 20 to 60 feet above water level, is a coal that has been faced at a number of places from below Hutson's branch up to Mill Creek, where it goes under drainage. It is about a thousand feet below the flint clay coal at the Jones place. It varies somewhat, but averages about 36 inches of solid, good-looking coal. Westward on Indian Fork at the Sam Walker opening it shows top and bottom benches of 20 and 38 inches of coal separated by 15 inches of clay. On the head of Aaron branch it has top coal 37 inches, bony shale four inches, coal 18 inches. Opposite the

Digitized by Google

mouth of Pemberton branch, it is 42 inches and solid. At Robbins it shows 31 inches of solid coal.

This coal is widely developed in Brimstone Creek basin and crops on the mid-slopes or near the base of the hills. It is the same as the coal mined at Glen Mary, Helenwood, Almy, Bear Creek and LeMoyne, and mentioned on page 136. At and near Almy there are a number of mines working it. It averages there 24 to 30 inches, and at Glen Mary has about the same average. The roof there is usually good and the coal is clean. Most of it is used as steam coal.

The coals in the New River and Upper Emory River basins are very imperfectly known and need extensive prospecting and much more study before any very broad statements may be made concerning them. Good coals undoubtedly exist in these basins, but before they can be developed, adequate transportation facilities must be provided and at reasonable rates, since competition is so keen today in the coal trade that a few cents difference in freight or other charges make the difference between success and failure.

Very much of the coal land in this northeastern field is owned by holding companies who lease it to operators at royalties that vary from 6 to 12½ cents per ton. The tendency in recent leasing has been toward the mean or minimum of the figures just given and the maximum royalty quoted above is regarded as high for present market conditions.

In marketing the output of this section, competition is more severe today than at any time in the past, since the development a few years ago of mines on the Louisville and Nashville and the Southern railways in the Clear Creek basin, added much to the local output, and at about the same time the opening of important new fields in southwest Virginia and the construction of new lines of road to deliver these latter coals to the mill section of the Carolinas and Georgia, further unsettled the coal trade and forced a readjustment in markets and rates that has not yet perhaps settled to equilibrium. Added to these conditions has been the fact that the State can produce coal materially cheaper than any private operator can, and so is in a position to quote prices when dull seasons come that are low enough to secure orders to keep her mines running and her

Digitized by Google

convicts busy, but that are so low they would quickly force any private company into bankruptcy.

To what extent in point of fact the State of Tennessee avails itself of this peculiar advantage that it undoubtedly possesses, the writer does not know, but it is generally felt among private operators that they are subjected in this way by the State to such unfair competition that there is a strong sentiment already developed among them that the State should take her convicts from the mines and place them on the public roads.

In a few years when the present seam mined at Petros is exhausted it would be very pertinent to raise the question—if, indeed, it should not be done now—whether the State should not abandon the policy of mining coal, as a matter of simple justice and fairness to her citizens engaged in the same pursuit and use her convicts in such road building.

In a rapid reconnaissance such as the one on which this report is based, it has not been possible to see more than sample areas of the various undeveloped sections and time has in the same way been lacking for following out the many problems of distribution and correlation that the studies in any one locality suggested. In this brief article it has furthermore not been possible to give more than a general glimpse of the field. Some of the description has been generalized so much that the local operator with his probably detailed knowledge of his own locality may regard it with scant favor. The attempt here, however, has been throughout, not especially to give him more knowledge of his own region than he now possesses, though this is doubtless true in some instances, but rather to give to the man who knows nothing whatever of this section of the State's coal area some general ideas of its coal content that it is hoped may be true so far as they go. It is hoped that detailed work may follow and that the enquiries of the man locally familiar with this or that section may be capable of satisfactory answer as a result of such work. Many courtesies and much information have been received during the work. It would be impossible to name all to whom the writer is thus indebted as the list would include every mining man from owner and manager on down, with whom the writer came in contact. He can not refrain, however, from expressing his great indebt-

Digitized by Google

ness to Mr. H. Murman, of Coal Creek, for much information with regard to the coals of that region with which his years of work have made him so familiar.

Digitized by Google

The Tennessee Coal Field South of the Tennessee Central Railroad

BY WILBUR A. NELSON.

INTRODUCTION.

Purpose and basis.—The purpose of this report is to give in a very general way much of the information that has been collected by the Geological Survey on the southern Tennessee coal field. It is a preliminary report in the strictest sense of the word, and will later be followed by a much more detailed one. Very little attention is given to stratigraphy, as it takes much detailed work to correlate correctly the coals over a large area, and this has not as yet been satisfactorily done. It will be taken up in the subsequent paper.

The report is based on a personal investigation, made to conform with the objects of this paper. The field work was done at odd times during the years of 1911 and 1912, and in all not more than a month or two was spent. Naturally many points were not visited, but as a whole the entire area was well covered.

LOCATION AND EXTENT.

General character, extent and relation.—This coal field is a part of the Great Appalachian field, which extends from northern Pennsylvania to central Alabama. In the northern part of the State are found the same beds as in Kentucky, and in the southern part the same beds as in Alabama. As this paper deals with the southern part of the field, the coals correspond more in general character to the Alabama coals than the Pocahontas coal of West Virginia or the Clearfield coal of Pennsylvania.

The coal field of Tennessee is the Cumberland Plateau which extends in a northeast and southwest direction across the State, forming the dividing line between Middle and East Tennessee. The field has an average width of from 35 to 50 miles. It covers practically all of Bledsoe, Cumberland, Marion, Mor-

Digitized by Google

gan and Scott counties; the western part of Anderson, Campbell, Claiborne, Hamilton, Rhea and Roane; nearly all of Grundy, Fentress and Van Buren counties; and the eastern side of Coffee, Franklin, Overton, Putnam, Warren and White counties. For a description of the northern part of the Tennessee coal field see the companion article on *The general features of the Tennessee coal field north of the Tennessee Central Railroad,* by L. C. Glenn.

Area of field.—In that part of the coal field south of the Tennessee Central Railroad, comprising 2,200 square miles, the area containing coal measures above the Sewanee conglomerate, comprises only 1,420 square miles, divided as follows: Walden Ridge 665 square miles; south of Van Buren County, 240 square miles; north of the Van Buren-Grundy and Van Buren-Bledsoe county line, 515 square miles. These figures show that in the southern counties much of the upper coal measures have been removed by erosion.

TOPOGRAPHY AND DRAINAGE.

Topography.—The Cumberland Plateau, which contains the Tennessee coal field, is a broad upland, standing about 2,000 feet above sea level. As a rule the surface is nearly flat, or only slightly rolling. The streams flowing out to the east, west, and south have cut many deep ravines in this upland, but in proportion to the broad upland, they occupy only a small part of the area. The result of this condition, is that the coals have been brought to the surface at a large number of points, at the same time, they have been greatly protected, so that in many cases almost as large an area of the beds remain as though they were entirely below drainage. These conditions prevail in the northern part of the field. It may be easily seen that the sandstones are not responsible for the general flatness of the plateau, for the surface bevels a number of massive sandstones as well as the intermediate less resistent shales and shaly sandstone. This is well seen in Walden Ridge, where the sandstone that protects the eastern edge of the plateau is stratigraphically 500 to 700 feet higher than the same sandstone which protects the western edge overlooking the Sequatchie Valley.

Digitized by Google

On the eastern edge of the plateau, there is a fairly even escarpment with a precipitous drop of about 1,000 feet, and the streams that drain this area lie at the bottom of long narrow gorges. On the western edge there is a similar drop, but the edge of the escarpment is not regular. It ramifies back and forth, forming numerous headlands separated by deep dendritic like coves. The ends of these headlands have in a few cases been cut off and now stand out as isolated outliers. The Sequatchie Valley extending nearly half way across the State in a general direction of north 30 degrees east, bisects the plateau in the southern half of Tennessee. This long narrow anticlinal valley ending in the Crab Orchard Mountains, which rise up nearly 2,000 feet above the valley, has its sides formed by the steeply upturned strata of the coal measures, which quickly flatten out in either direction from the valley escarpment. The average height of the plateau along this valley is about 1,000 feet, but on the eastern side going north, one sees an imposing array of knobs, which extend up about 1,500 feet. These knobs, as well as the Crab Orchard Mountains at the head of the valley, are the remnants of the anticlinal mountain that once existed here. In the Crab Orchard Mountains, which rise above the general level of the plateau, we do not get the higher coal measures, but instead the lower ones lifted about 800 feet above their general level in the Southern Tennessee field.

In the coves and passes of these mountains limestone occurs on top of the plateau. At one place it forms the floor of a large cove of over 8,000 acres, which is completely surrounded by mountains, and is drained by the waters passing into a large limestone cavern. The exit from this cavern is in the head of Sequatchie Valley, where the water comes out as a large spring.

Drainage.—All of the drainage of the plateau is cared for by the tributaries of either the Tennessee or Cumberland rivers. In the field south of the Tennessee Central Railroad, all of the drainage, southeast of a line extending from the Tracy City branch of the Nashville, Chattanooga & St. Louis Railroad to the Crab Orchard Mountains, is into the Tennessee River; the remainder of the plateau is drained by streams flowing into the Caney Fork, a tributary of the Cumberland.

Digitized by Google

On Walden Ridge, the watershed is never more than a half mile from the escarpment along the Sequatchie Valley, practically all of the drainage going directly into the Tennessee River, through White, Fall, Piney, Roaring, Rocky, Opossum, Soddy, Chickamauga and Suck creeks, and their tributaries. All of these creeks have formed deep and narrow gorges, which wind into the ridge and afford suitable places to tap the coal measures. The early development of the coal fields of Walden Ridge, was due primarily to this fact. The short streams that flow down the west side of the ridge, empty into the Sequatchie River, a tributary of the Tennessee. The long drainage to the east on Walden Ridge, is due to the surface of the ridge being practically a dip slope, extending from the knobs along the Sequatchie Valley to the eastern escarpment, a distance of from eight to ten miles. The water flowing down this slope gradually cut down the deep gorges of the present.

In the northern part of the Sequatchie Valley, the drainage on the western side is as short as on the eastern side, but southward the drainage area increases, the creeks becoming larger. Near the southern end, Little Sequatchie River and Battle and Crow creeks are from 15 to 25 miles long. These flow nearly south and drain the southern part of the Sewanee Basin. The divide between the gorges of these streams flowing south and the ones flowing north is very narrow and from a half mile to several miles wide.

The drainage of the western edge of the plateau is through Caney Fork, which rises in the northwestern part of Cumberland County; and its tributaries, of which the main ones are Calf Killer, Rocky, Collins, and Elk rivers. These so-called rivers have cut deeply into the plateau, and are the largest and longest streams of the area. The gorge or "gulf" as it is called, of the Caney Fork is deep and narrow, and cuts directly into the heart of the mountains and down through the coal measures into the underlying limestones. In this gorge the Caney Fork flows in places on the surface, in places through underground channels, until it reaches the edge of the plateau, where it is a turbulant stream with a large volume of water, soon to be utilized by the erection of an 80,000 horse-power hydro-electric

Digitized by Google

plant, which will furnish power to the country in a radius of several hundred miles.

Southward along the western edge, the "gulfs" become wider, and long, wide coves, that cut up this part of the field into a dendritic-like area from which much of the coal has been removed, make their appearance. These streams carry large amounts of water in the winter and spring months, but during the summer and autumn become very low, many of their branches on the mountain drying up entirely. Much of the water that falls on the plateau soaks into the ground, and down to the limestone, where after passing through underground channels or caves, it comes out as deep-seated springs. Many caves occur around the base of the plateau, some of which contain deposits of alum, salpeter and cave onyx.

GEOLOGY.

Kinds of rock.—The Cumberland Mountains, which are the depository of Tennessee's seams of coal, are of Carboniferous age. The rocks are all of sedimentary origin and consist of more or less pure layers of limestone, shale and sandstone. The valleys and lower slopes of the mountains are of limestones and shales interbedded. The upper part of the slopes and the top of the plateau are composed of a series of sandstones and shales. It is in these shales that the coal seams occur. In the southern part of the field the sandstones, shales and coals vary in some particulars from the same measures in the central part of the field, that is, in Cumberland County. In Marion County the lower series of sandstone, shales and coals are well developed, while the higher members have been almost entirely eroded.

In Cumberland County and vicinity, the lower measures are wanting in many localities. The upper members, which capped only the low hills on the Cumberland Plateau in the southern section, cover the entire plateau surface in the central part of the field. These upper members contain many coal seams. Several of the seams are workable and well known mines are located upon them.

In the preceding discussion the southern field is shown to differ considerably in its northern and southern parts. In the

Digitized by Google

discussion of the geology and coals, the southern field will be divided into three districts, as follows: Tracy City, Bon Air and Walden Ridge.

Tracy City district—geology.—The geology of this region is well shown by two sections, one at Tracy City, the other at Orme. The main rock is a very heavy conglomeratic sandstone known as the Sewanee sandstone about 100 feet thick.

As the Sewanee conglomerate is traced northward, it thickens considerably, and may pass into the sandstone either above or below it. At the falls on Fall and Cane creeks in Van Buren County it is 300 feet thick. Here it is a mass of hard rocks, with a well developed conglomeratic phase. Still further northward from this point, the sandstone divides into an upper and lower member, with a 60-foot shale intervening. This was seen in the gorge of Bee Creek at Herbert. On Cane Creek, the 300-foot sandstone mentioned is the first sandstone which occurs above the limestone. The upper 50 or 75 feet of this mass is a soft honey-combed sandstone which contains a large per cent of efflorescent material, probably epsom salts. Just above the Sewanee conglomerate, lies a shale in which occurs the main coals of this region, called the Sewanee coal. There is sometimes a coal lead directly on top of the Sewanee sandstone. The lower Sewanee occurs 30 feet above the conglomerate, while the upper Sewanee occurs 30 feet higher. There sometimes occurs a thin, shaly sandstone between the upper and lower Sewanee coals. The shale member extends up some distance above the upper Sewanee coal, and is overlaid by an 80- to 140-foot sandstone, which is soft and coarse, and colored red or orange in places.

Below the Sewanee conglomerate, occurs a series of sandstones and shales, which extend down to the limestone, reached at a distance of 80 to 200 feet. The difference in the thickness of these lower measures is due to the very irregular old land surface upon which they were deposited. The sandstones are non-conglomeratic, hard, and fairly pure. The shales all contain thin seams of coal which come and go. The only place at which any of these lower seams is mined commercially is at Orme, Tenn. This seam occurs directly under the first sand-

Digitized by Google

stone below the Sewanee conglomerate. All the other seams are too thin to work.

Tracy City district—structure.—The rocks in this region have only very low general dips except along the southeastern edge of the area, where part of the western limb of the low anticlinal fold, which formed the Sequatchie Valley, still remains uneroded and forms the escarpment to the valley.

At Altamont in the center of Grundy County, limestone occurs in the bed of a stream, due to a pronounced rise of the strata at this place, which brings the limestone up above its general elevation.

Bon Air district—geology.—This region contains a much thicker coal section than the southern area just discussed. Nearly all of the sandstones are conglomeratic in some locality, but often where one of them is markedly so the other members are lacking in this character. Sections at Bon Air, Clifty and Crab Orchard show in general the rocks as they occur in this area.

The section at Bon Air shows the main sandstone of this region. It is a heavy, hard sandstone, about 100 feet thick, with a conglomeratic phase near the top. This sandstone forms a high bluff over a wide area. The pebbles are white quartz and vary in size up to about one-half inch in diameter. Between the sandstone and the underlying limestone, there occurs only one shale, which varies from dark to light bluish-gray. It is in this shale that the well known Bon Air coals occur. The upper Bon Air seam lies about 50 feet below the bottom of the overlying sandstone, while the lower Bon Air seam is about 20 feet beneath the upper Bon Air. There is a third seam at this locality that rests on the limestone which occurs six feet beneath the lower Bon Air coal. It would be well to state that another vein of coal occurs at many places in this locality just below the heavy 100-foot sandstone. This is the Ravenscroft coal.

At Clifty, a mining town in Cumberland and White counties, a good section occurs, which is shown above. The lowest rock is a very heavy conglomerate, which occurs in the bed of Caney Fork River at this point. The limestone comes in just below this sandstone, but it is not seen at this point. Above this is a

Digitized by Google

60-foot shale, very clayey and bluish-gray in color, which contains red bands of about one inch thickness. It is possible that a coal occurs in this shale near the top. The next member of the series is a 40-foot sandstone composed of thin and heavy beds containing shale partings in its lower half. In color, it is yellowish, with shades of red.

Above this sandstone, occurs a 60-foot clay shale, grayish in color, containing locally a thin sandstone, which appears about 20 feet from the base of the shale. In this shale occurs the workable coal of this locality, which is about 15 feet above the underlying sandstone. This is the Clifty coal. At the base of this shale occurs another coal seam. The next member of the series is a heavy, coarse sandstone, 50 feet thick, which caps the tops of the hills at Clifty. Where none of it has been eroded, it reaches a thickness of 100 feet. From work done by Mr. Chas. Butts of the U. S. Geological Survey and by the author in the summer of 1911, it appears that the Clifty and Bon Air seams are the same.*

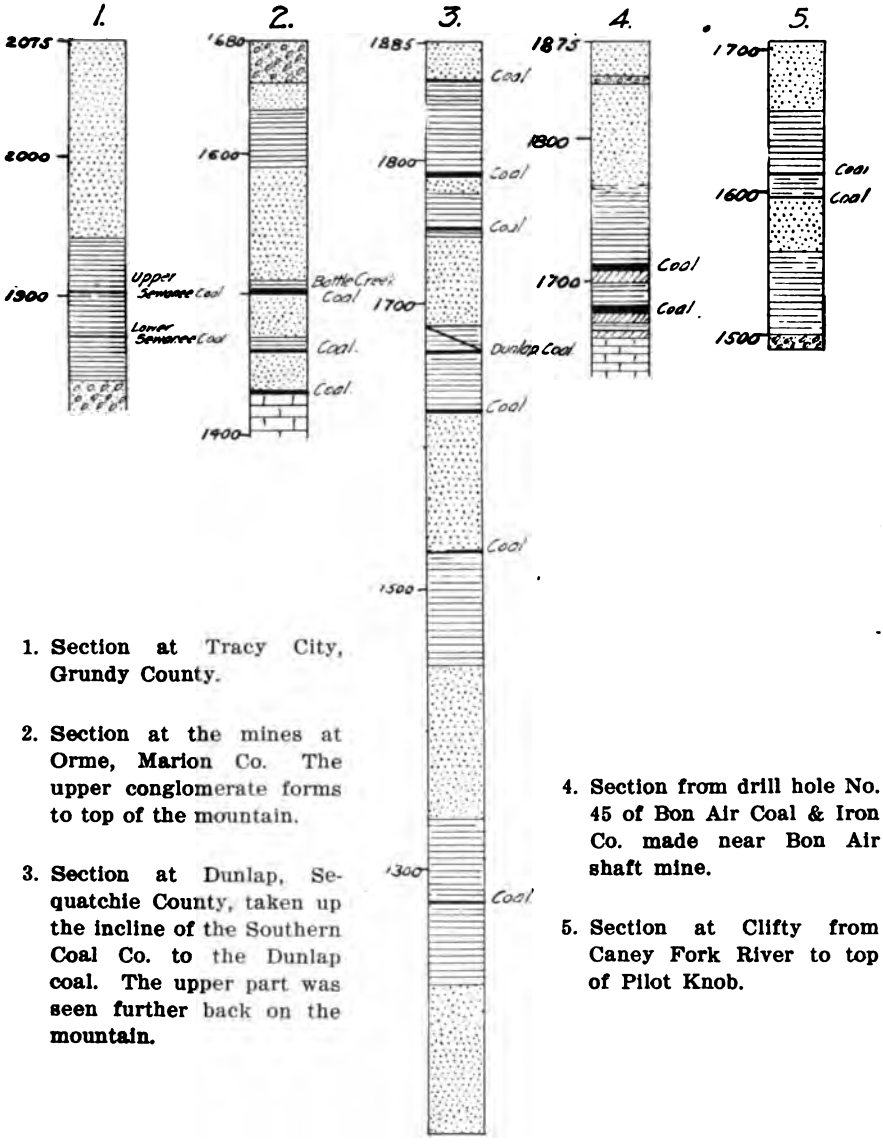
The sixth section given, was taken along the Tennessee Central Railroad just west of Crab Orchard, Cumberland County, where the rocks are exposed on end, and have dips of from 15 to 75 degrees approximately west. The entire series of the coal measures outcrops on the surface and is crossed by the railroad in several cuts at this place.

At the base of the section is a heavy sandstone conglomerate, which dips about 75 degrees. Just to the east is a slight fault, and the next rocks seen are the limestones which underlie the coal measures. The upper several hundred feet of the section is composed of a series of clayey sandstones, and sandy shales. The characteristic red or orange color of these sandy shales can not be mistaken after they have once been seen. The top sandstone is the Rockcastle sandstone, mentioned in several of the U. S. Geological folios of this region.

Bon Air region—structure.—In most of this region the rocks are nearly level, and the dips are so slight that one can

*Subsequent work shows that the Clifty coal is a higher one than the Bon Air. The shale in which the Clifty coal occurs thins out to the west of Clifty, and the sandstone beds above and below it come together and form the heavy bluff at Bon Air.

Digitized by Google



1. **Section at Tracy City, Grundy County.**

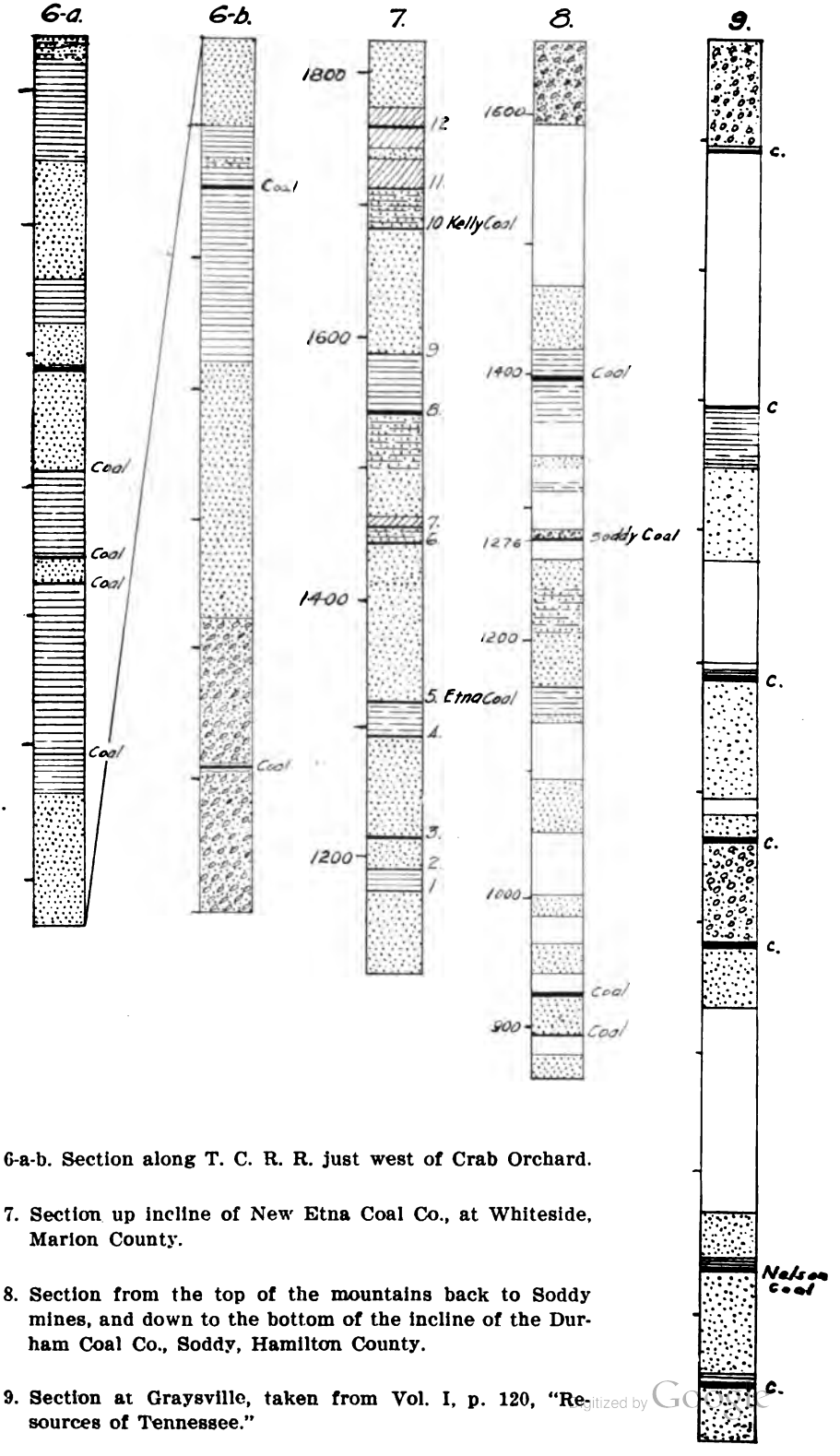
2. **Section at the mines at Orme, Marion Co. The upper conglomerate forms to top of the mountain.**

3. **Section at Dunlap, Sequatchie County, taken up the incline of the Southern Coal Co. to the Dunlap coal. The upper part was seen further back on the mountain.**

4. **Section from drill hole No. 45 of Bon Air Coal & Iron Co. made near Bon Air shaft mine.**

5. **Section at Clifty from Caney Fork River to top of Pilot Knob.**

Digitized by Google



6-a-b. Section along T. C. R. R. just west of Crab Orchard.

7. Section up incline of New Etna Coal Co., at Whiteside, Marion County.

8. Section from the top of the mountains back to Soddy mines, and down to the bottom of the incline of the Durham Coal Co., Soddy, Hamilton County.

9. Section at Graysville, taken from Vol. I, p. 120, "Resources of Tennessee."

Digitized by Google

tell that the rocks rise or fall only by comparing their elevation above sea level at points a half mile or more apart. Nevertheless, the structure in this region is much more pronounced than in the Tracy City region. As before mentioned, the rocks along the Sequatchie Valley dip steeply to the west, but they flatten out at a distance of a half mile from the escarpment. From the head of the Sequatchie Valley to Crab Orchard, along the west edge of the Crab Orchard Mountains, the same conditions prevail. The fault which lies on the western side of Sequatchie Valley also extends northeastward along the western edge of Crab Orchard Mountains, and has been noted at several points. Another fault* was recently traced and mapped by Mr. Chas. Butts, of the U. S. Geological Survey, and the writer in the summer of 1911. It occurs in Cumberland County and extends in a southwest direction from a point just south of Crossville to near the place where Cumberland, Bledsoe and Van Buren counties meet. This zone of disturbance passes just west of Lantana, Cumberland County, where it is well marked.

Walden Ridge district—geology.—This area is a long narrow ridge cut off from the Cumberland Mountains on the west by the Sequatchie Valley, and extending northeast parallel to and along the eastern edge of the Cumberland Mountains to Morgan County. The Raccoon Mountains, which lie just south of the ridge and west of Chattanooga, will also be considered under this head.

In the southern part of this area the sandstones on Walden Ridge have thickened considerably. This is well shown on Lookout Mountain, an outlier of the ridge, where the main bluff is over 200 feet high. On the ridge proper, just north of Chattanooga, the sandstones are still very thick, and at Suck Creek a bluff was noted nearly 200 feet thick. As you go north-

*Field work done subsequent to 1911 would require the remainder of this paragraph to read as follows: There is a zone of folding of the rocks, with possibly some faulting, extending from a point just south of Crossville to near the point where Cumberland, Bledsoe and Van Buren counties meet. This zone of disturbance passes just west of Lantana, Cumberland County, where it is well marked.

Digitized by Google

ward the conditions change and the main sandstones thin considerably.

Sections seven, eight, and nine show to best advantage the conditions as they exist in this area.

The Etna section was made along the incline of the New Etna mines at Whiteside, Marion County. The lowest rocks here exposed are thin beds of sandstone and shales with a few thin coal seams. The Etna coal, the first coal worked, occurs in the lower half of the section at the base of a heavy sandstone about 100 feet thick, which here stands out as a high bluff. Several feet of thin-bedded, hard flagstones lie at the base of this thick bedded sandstone. At the point where this section was made, there were no signs of a conglomeratic phase, but about one mile from here two such well marked bands were found near the base of the bluff. They were approximately four feet thick, and separated by about 15 feet of sandstone. The gray shale in which the coal occurs, is sandy in places, and has a slaty appearance. Below this is a thin-bedded, whitish-gray, pure sandstone. About 150 feet above the top of the first heavy bluff, another bluff-forming sandstone occurs. Between these two bluffs are a few sandy shales and shaly sandstones. A heavy-bedded, massive sandstone about 100 feet thick composes the upper bluff. It is coarse grained and soft in many places, and has a yellow color, which occasionally has a reddish tinge. Directly on top of this upper sandstone bluff occurs the Kelley coal, the principal seam of this region. Two other coals lie in this 80-foot shale, whose lower part is very sandy. The next member of the series is a heavy 50-foot sandstone, which caps the hills at this point. There are twelve seams of coal that were noted in this section.

The Soddy section was made up the incline to the Soddy mines, and from thence along the road to the top of the mountain. The lower 300 feet of the section is composed of thin, alternating beds of sandstones and shales. These thin, white, or light-yellow sandstones are often either ripple-marked or cross-bedded. The shales, which contain a few thin coals, are often sandy and generally have a yellowish-gray color. Above this series is a thick 100-foot sandstone, the lower 40 feet of which makes a thick, cross-bedded, hard, sandstone bluff. The

Digitized by Google

upper part of this bed is composed of a thinly laminated cross-bedded sandstone with shaly streaks intervening. The next member of the section is a thick, bluish-gray, clayey shale containing the Soddy coal, which occurs 15 feet above the underlying sandstone. The lower 50 feet of this shale, contains several thin sandstone bands. Above this is a thin sandstone, overlaid by about 60 feet of iron-stained gray shale, partly sandy, and partly clayey. Twenty feet from the top of this shale is a coal seam. Overlying the shale is a hard, cross-bedded, yellow sandstone, 50 feet thick, which sometimes forms a low cliff. This is followed by 120 feet of covered mountain side, which is probably a sandy shale. Above this and capping the mountain is a heavy and massive yellowish-white, bluff-forming sandstone conglomerate. It is full of white quartz pebbles, up to an eighth of an inch in diameter, and in places, the upper portion of the bed shows a few mud cracks.

The last section, which is very similar to the one at Soddy, is one taken near Graysville, where they are mining the lower measures. A description of this area occurs in Volume I, *Resources of Tennessee*, pages 117 to 163.

Walden Ridge—structure.—The rocks of the ridge have a gradual southeastward dip from the Sequatchie Valley, where the layers of sandstones and shales are steeply upturned toward the west. One-half a mile from this valley escarpment the rocks appear to lie flat, but at that point an almost perfect dip slope sets in across the ridge, which extends within one mile of the eastern bluffs, at which point the plateau is 300 feet lower than on the western edge. Again on the eastern edge of the ridge the rocks have steep dips, but in a northwestern direction. Walden Ridge is really a syncline with a long western and short eastern slope. On account of this eastern slope, the mines on the eastern side are located in the heads of the ravines where the rocks are more level.

COAL VEINS.

TRACY CITY DISTRICT.

The Tracy City district includes all of Grundy County and parts of Bledsoe, Franklin, Marion and Sequatchie counties. The reason for thus grouping them is that the coal

Digitized by Google

Entrance to Battle Creek Coal Co.'s mine at Orme, Tenn.

Inside of mine at Orme, Tenn., showing 20-foot vein of coal.

Digitized by Google

development in these southern counties has all been partly correlated with old workings at Tracy City, where the Sewanee coal is mined.

Workable seams.—In this area the Sewanee coal is the main workable seam. The only other seam worked south of Tracy City is one of the lower veins known as the Battle Creek coal. These two coals are easily located, for their horizon varies very little.

Sewanee coal.—The main Sewanee seam occurs about 50 feet above the top of the only heavy sandstone conglomerate of this area. This sandstone is here coincident with and forms the surface of most of the general plateau, and on it lies numerous low hills, the only remnants that are left of the higher measures. It is in these hills that the Sewanee coal seams are found. Only the upper vein, which varies greatly in thickness, is worked. Although many measurements show the seam to be five or six feet, and some as high as ten or more feet, the general average is from three to three and a half feet. The floor of the seam is a very plastic grayish-white clay, or a gray shale. Above the seam is a very fossiliferous gray shale, carrying a large variety of plant impressions.

Battle Creek coal.—The horizon of this coal, as already mentioned, is at the base of the first heavy sandstone below the Sewanee conglomerate, which also forms the main bluff in the southwestern part of the coal field. This seam is one of the most uncertain veins worked in Tennessee, for it varies greatly in thickness, changing in a few feet from the thickness of a pencil-mark to a 20-foot vein. The troughs in which the coal occurs extend in a direction north 50 degrees east. In places the coal in the rolls is solid, but at other points the hard coal is divided into four benches of about the same thickness, separated from each other by an inch or two of soft bony coal. At the base of the lowest hard coal bench, there occurs in places a bench of soft coal which varies from nothing to two feet in thickness. Again small lenses of cannel coal occur, entirely surrounded by the hard coal. There is very little kidney sulphur present, but sulphur occurs in the form of flakes. The coal is hard bituminous, and shows practically no slacking on exposure.

Digitized by Google

The roof of the seam is hard, fairly pure sandstone, while the floor is sandstone where that is not overlaid by several feet of grayish-white clay. This clay occurs as a rule where the coal is thin, and even then it often is lacking. The horizon of this coal underlies the whole southern part of the plateau and has been widely prospected, but has not up to the present been found in quantities favorable for mining, except at Orme, Tenn.

Some other coals are worked in this district, but as this is done only in Bledsoe County, these seams will be described under the description of that county. They are the Richland, Morgan Springs and Angel coals.

EXTENT OF COAL MINES.

Bledsoe County.—This county is divided into three sections extending in a northeast and southwest direction; they are the western third, located on the Cumberland Mountains, the central third in the Sequatchie Valley, and the eastern part on Walden Ridge. The horizon of the Sewanee coal underlies most of this county on the Cumberland Mountains. Active mining is carried on only at Atpontley, in the southern part of the county. The rocks at this point dip somewhat, and as in other places on the edge of Sequatchie Valley, mining conditions are far from ideal.

The coal, which is somewhat mashed, ranges from three inches to six feet, and contains a clay parting which varies from one to twelve inches. This parting occurs anywhere from the top to the bottom of the seam. The coal is probably the Sewanee seam.

The area around Pikeville recently has been thoroughly discussed by W. C. Phalen, of the U. S. Geological Survey, in an article which appeared in Volume I, No. 4, *Resources of Tennessee,* which can be obtained from the State Geologist. The Richland and Angel coals are the main veins described in this paper. The Richland is probably the same as the lowest Sewanee coal, as it occurs directly on top of the Sewanee conglomerate, while the Angel coal occurs just below that formation and is a very persistent seam. The Morgan Springs coal, which lies directly under the upper cliff-forming sandstone has

Digitized by Google

not exceeded two feet in thickness wherever prospected. It is a good clean coal, and may occur in some localities in workable thickness. The Angel bed is being worked in an 8-foot vein on the Stephen Gap road, in Bledsoe County, just below the county's northern line, where it is mashed and dips about 25 degrees. The Richland coal is only about two feet thick around Pikeville. The main or upper Sewanee is the principal coal and has been opened in numerous places along the western boundary of the county, where the seam is well developed, and shows from three to four feet of coal in many prospects.

On the State coal lands of the Herbert Domain, in the northwestern part of the county near Herbert, the coal in one opening shows a thickness of 71 inches, but at this point the rocks are slightly disturbed and the thickness of the coal is abnormal.

Franklin County.—The Sewanee coal occurs in this county only in three comparatively small hills between the town of Sewanee and the county line just east of it. The Nashville, Chattanooga and St. Louis railroad cuts through a sag in one of these hills, at which point the coal outcrop can be seen. Practically all of the coal has been worked out of these hills, and the mines abandoned. It is from these deposits that this coal gets its name, although the original Sewanee mines were in the coal seam at present called the Battle Creek coal.

Several spurs of the Cumberland Plateau, which contain the coal veins below the Sewanee conglomerate, extend out into Franklin County. Such is the spur up which the Nashville, Chattanooga and St. Louis railroad branch line from Cowan to Tracy City runs, and on which the town of Sewanee is located. The one of the ramifications of this ridge which extends south from Sewanee along the county line, also contains the Battle Creek seam. West of the main line of the Nashville, Chattanooga and St. Louis railroad from the Cowan tunnel to the Tennessee-Alabama state line, are some outliers of the Cumberland Mountains, which are capped by the lower coal measures in which the Battle Creek seam has been prospected, without success.

Grundy County.—All of the county that lies on the plateau is underlaid by the lower measures, which contain several seams, none of which have been found workable. The Sewanee

Digitized by Google

coal is worked extensively in this county, at Tracy City, Coalmont and Clouse Hill. The main operations are now at Coalmont and around Tracy City. Circling around the eastern side of Tracy City and from there extending northward about six miles is a long narrow ridge, which at its end spreads out and covers several square miles, and is underlaid with the Sewanee coal. The mines at Coalmont are situated at its northern end. East of Coalmont and along the county line is an area in Grundy county a mile or more wide, which also contains the Sewanee coal. This is known as the Tatesville region, and probably will be the next one developed, as extensive prospecting, which shows a large body of coal, has been carried on in the last few years. The lack of a railroad in this territory is all that has prevented the development of this section.

Marion County.—The part of this county that lies on the Cumberland Mountains is greatly cut up by the ravines and coves which ramify back and forth into the plateau. The upper measures have been eroded away from most of this county, but two small areas occur on the promontory between the Little Sequatchie River and Fiery Gizzard Creek. The road from Sequatchie to Tracy City passes over one of these areas, while to the other there is an extension of the Nashville, Chattanooga and St. Louis Railroad from Tracy City. A large area of Sewanee coal exists in the northern part of the county on the spur of the mountain between the Little Sequatchie River and the Sequatchie Valley. The mines at Whitwell are located on this area. There is a large body of coal in this region, and development is only held back by lack of transportation.

The Battle Creek coal is worked at Orme, Tennessee, in the southwestern corner of the county, as has already been mentioned. In the past, a number of mines have operated on the coal in this area, which is that part of the Cumberland Mountains which lies from South Pittsburg west to the county line.

Sequatchie County.—This county is divided into three natural divisions by the topography of the region. The western third lies on the Cumberland Mountain, the central third lies in the Sequatchie Valley, and the eastern third on Walden Ridge. The Sewanee seams occupy practically the entire part of the county that lies on the mountain. Drill records show a

Digitized by Google

vein of good thickness. Mining is carried on at only one place, Dunlap, where the coal is 48 inches thick. At the mine entrance the seam is split by an 18-foot clay lens, which thins down to three inches toward the north and disappears entirely towards the west. A section is given at this point on page 163, which shows rashy coal 40 inches thick just above the heavy Sewanee conglomerate. At a distance of 40 feet above the conglomerate, the main Sewanee seam occurs. Instead of the sandstone above this shale capping the highest hills of the mountain as it does around Tracy City, the measures rise higher, and one finds at this point another thick shale in which three coal veins occur. The lower of these seams lies directly on top of the first sandstone above the conglomerate, and at this point measures 18 inches. Thirty-five feet higher, occurs the second seam, which is 20 inches thick, but made up entirely of rash coal. At the top of this shale about 70 feet higher, is the third seam, containing 18 inches of coal, directly underlying the cap rock of the mountain, which is a soft, white, coarse sandstone. North from this county the same conditions prevail. These upper coals are found in many of the hills while those below the Sewanee conglomerate, as elsewhere, occur in irregular pockety seams.

BON AIR DISTRICT.

This District is comprised of that part of Cumberland and Putnam counties south of the Tennessee Central Railroad, and the part of Van Buren and White counties that lies on the plateau.

Workable coals.—The main coals of this area are the Bon Air coals. They are extensively mined at and around the town of Bon Air, where they occur in the shale under the first heavy bluff-forming sandstone. At the top of this shale the Ravenscroft coal occurs.

Ravenscroft coal.—The Ravenscroft coal, which averages 54 inches, is a hard, bituminous coal, containing some sulphur, and makes an especially good domestic fuel. It is covered by a sandstone roof and has a bluish-gray, clay floor. In places there occurs several inches of rash at the base of the coal.

Digitized by Google

Bon Air coals.—There are two Bon Air coal seams, an upper and a lower, which are separated by about 20 feet of clay and shale. In places the upper seam is worked, and again it is the lower vein which is the thicker. Often there is a third seam, or one might say an under rider of the lower Bon Air, which occurs five or six feet below it and is separated from it by clay. This seam rests on limestone, or is separated from it by a foot or two of clay. From field observations it appears that where one of the Bon Air coals occurs in workable thickness the other is too thin to be utilized. In the shaft mine the seam averages 36 inches. It must not be thought that the only coal found immediately above the limestone strata is the Bon Air, for this is not so. The line of contact between the limestone and the overlying coal formation is a line of unconformity. That is, the rock series is broken, and some of the members are missing, because they were never laid down. In this manner as one travels from the east to the west, it is seen that the lower coal measures are gradually cut out. For example, the coals that lie next to the limestone along the eastern edge of Walden Ridge are many feet lower stratigraphically than the coals that lie next to the limestone along the western escarpment of the Cumberland Plateau, as at Bon Air and Sewanee.

Sewanee coals.—At Eastland and Clifty, situated along the Cumberland-White County line, the coals mined in the top ridges are called the Clifty coals. There are two veins which occur at this point, the lower one occurring directly on top of the sandstone upon which Clifty is built, and the upper one about 15 feet higher and separated from it by shale. The upper coal, which is soft and slacks very easily, is the main seam and is the one generally worked. It contains too much sulphur to permit of making commercial coke. At Eastland the seam averages 48 inches, and has a bluish-gray shale roof, and a gray clay bottom. At Clifty, about a half mile distant, the coal in one of the mines averages 48 inches and 42 inches in another. The floor of the seam is gray clay, and the roof is bluish-gray shale or a thin sandstone.

The Morgan Springs coal, which is of good quality and clean, has been worked in a few local banks, but is too thin to mine commercially.

Digitized by Google

Cumberland County.—This large county is divided by the Tennessee Central Railroad in a northeastern and a southwestern area of nearly equal size. The southwestern area only will be discussed in this article. The remainder of the county is described in the companion article, by Dr. L. C. Glenn. The eastern edge of the county lies along the Sequatchie anticlinal fold, which forms the Sequatchie Valley and Crab Orchard Mountains.

The coals along this line have been worked locally; but as the rocks have dips which range from 15 to 75 degrees the mashing is so great, that all the mines opened in this area have been closed. In the section given along the Tennessee Central Railroad just west of Crab Orchard, the thickness of the different coal outcrops from the bottom to the top are as follows:

A lead that had somewhat the appearance of coal was noted in a much mashed five-foot shale which occurred in the middle of the lowest conglomerate, where the dip was 70 degrees.

The next coal, which measured 20 inches and occurs in the first shale, was being opened at the time this locality was visited. This seam, which is probably the same as the coal at Monterey is said to vary from 18 inches to five feet.

The next or second shale contains two coals, one 30 feet from the bottom and the other at the base of the overlying sandstone, which has a dip of 25 degrees. The thickness of the lower coal is 36 inches, while that of the upper is 12 inches. In the third shale, there are also two coal horizons, one occurring at the top and the other at the bottom. The coal at the lower horizon is 16 inches thick, and has a sandstone bottom and shale roof. The upper coal horizon, at the base of the overlying sandstone, shows only a thin coal blossom. The two higher shales at this point do not show any coal horizons.

About one mile west of Crab Orchard these measures flatten out. The upper sandstone of the Crab Orchard section covers a large part of the surface of the plateau in this county, but along the southeastern border only the lower 200 feet of the coal measures remain. There is also a low anticline occurring southwest of Crossville, accompanied by abrupt folding along a line of disturbance. The main disturbance starts one and a half miles east of Leggett and extends about eight miles in a

Digitized by Google

general direction south 60 degrees west, passing about one and a half miles west of Lantana, and one mile south of Pott's Knob, and Flat Rock school house. From this last point it has been traced about eight miles further in a direction of about south 30 degrees west, passing just east of Thomas Spring School, and leaving the county at a point about two and a half miles west of Newton.*

There are also two small folds about four miles long which run roughly parallel to the main one, one to the east of it, and one to the west. The eastern one runs about one-half mile west of Lantana, and the western one extends from about one-half a mile south of Legget for a distance of four miles, the other end being one-half a mile south of Anderson Knob. This region of folds was first recognized by Safford many years ago at Lantana, where a bed of mashed coal was mined by stripping off several feet of soil under which it occurred. Where the formations are undisturbed in this region, the main coals lie from two to six hundred feet under the surface, and not much is known concerning them, as very little drilling has been done.

Putnam County.—Only the eastern edge of this county lies on the Cumberland Mountains, and but part of it is south of the Tennessee Central Railroad. At Monterey the section is somewhat similar to that at Bon Air. The one heavy conglomeratic sandstone present forms massive bluffs at this point, is the surface rock on the border of the plateau, and has a seam of coal at its base. Eastward some of the upper sandstones and shales appear, and at Dripping Springs there are about 200 feet of sandstone and shale present above the heavy bluff sandstone which occurs at Monterey. The main coal occurs under the bluff at Monterey, and is probably the same as the Ravenscroft seam. Several inches of rashy coal at the base of the soft, red conglomerate, upon which Dripping Spring is situated, was the only other vein noted.

Van Buren County—The coal resources of this county are entirely undeveloped and the only mining is from small banks and for local use. The eastern part of this county, and espec-

*This was observed in working the geology of the Crossville folio, which will be published by the U. S. Geological Survey.

Digitized by Google

ially the southeastern corner, is underlaid by one or more rich veins of coal, while around the post-office of Gillentine in the southern part of the county, numerous openings have been made on the coals, which show that several seams are of workable thickness. A bank about one mile north of Gillentine, which is said to be on the Sewanee seam, shows 44 inches of coal, and has a roof of eight inches of shaly clay covered by a thin sandstone. This is a coal which shows little weathering, and has a small cubical cleavage.

At Robertson Springs is an opening which measures 54 inches; on Glady Fork one that measures 52 inches; while at the old Oleo postoffice a prospect shows 48 to 52 inches of coal, all supposed to be on one of the Sewanee seams. They lie above the heavy sandstone which forms the mountain escarpment just west of this area, and probably corresponds to the coals worked at Sewanee.

Under the bluffs which occur around the head of Rocky River and its tributaries, openings have been made on what is probably the equivalent of the Ravenscroft seam. One of these openings, which was made where the water of Double Branch falls over the bluff, shows a 38½-inch seam, divided into two benches. The upper bench consists of ten inches of hard coal, separated by 13 inches of slate from the lower bench, which contains 16½ inches of good coal. These measurements were taken at the outcrop. It is said that the slate thins down to several inches at the end of the drift and that the coal thickens. The roof of this seam is hard sandstone and the floor is clay.

Around the town of Spencer, these upper and lower seams occur in about the same thickness as at the points just mentioned, and coal from them is used locally.

White County.—Only the eastern part of this county contains the coal measures of the Cumberland Plateau. The main mines on the Bon Air seam occur around the town of Bon Air, while in the northeastern corner of the county the Ravenscroft coal is worked. At Eastland and Clifty, on the middle-eastern border, the supposed Sewanee seams are operated. These localities have already been taken up under the head of "Bon Air district" on page 173, in the description of the type seams of coal.

Digitized by Google

On the U. S. Geological Survey areal map of the Pikeville sheet, the country where the present Clifty extension of the Nashville, Chattanooga and St. Louis Railroad crosses Clifty Creek, is shown as containing only the lower coals, but recent work has proved that the upper coals occur. The rocks are somewhat disturbed at this point and have local dips of 5 to 10 degrees, so that limestone beneath the Coal Measures outcrops in Clifty Creek a half mile below the N., C. & St. L. Ry. bridge. A coal probably in the first shale above the Bon Air coals, has been opened at this point and shows a thickness of 24 inches, with a one-inch parting near the center. In the shale above this one, another coal, which shows a thickness of from 25 to 38 inches, has been opened up in several places. One of these prospects which occurs on the side of the Eastland hills just above the Nashville, Chattanooga and St. Louis Railroad is as follows: Clay shale roof, 23 inches of coal containing kidney sulphur, five inches of rash, and a floor of gray clay. A coal is exposed under the falls of Jennings branch, which is near Stringtown. The seam has a sandstone roof, slate bottom and is 45 inches thick. Its section follows:

	Inches
Soft coal	19
Rash	1
Cannel coal	21
Soft	4
Total	45

The limestone outcrops 20 feet below the seam. These few localities cover the county and show in general the condition of the coal measures.

WALDEN RIDGE DISTRICT.

Coals of Raccoon Mountain.—The coals of the Walden Ridge district have been mined in many different localities and for many years. There are at least twelve coal horizons, but often many of them are wanting, and only one or two of those that remain are of workable thickness. These seams, where they occur on the New Etna Company's property at Whiteside, have all been named. In the section at that point, given on page 164

Digitized by Google

the coals are numbered, and these numbers will be used in referring to them. Number 1, the Mill Creek seam, is a very rashy coal about four feet thick with a clay parting, which varies from one to six inches in thickness in the middle. The coal above this parting is not very rashy. Number 2, the Red Ash seam, occurs 42 feet above the Mill Creek vein. It is a very good, clean coal from 4 to 30 inches thick, which on burning leaves a red ash. Number 3, the Dade seam, occurs about 25 feet above the Red Ash. It was covered at the time of the visit, so no measurements could be taken, but is here a thin coal. Number 4, called the Battle Creek coal, is clean, hard coal, which has a thickness of 14 inches, and a shale roof and bottom. Number 5, the old Etna coal, was the original coal mined at this point. It is hard, pockety coal, which shows little weathering and varies from two inches to seven feet in thickness. The top of the seam is the base of the lower cliff-forming sandstone, while the bottom is shale or clay. Number 6, which has no name, is only a thin coal blossom, which occurs on top of the sandstone just mentioned. Number 7, which is called the Whitwell seam, occurs about 15 feet above No. 6, but no measurements could be taken, as the coal was not opened. Number 8, called the Weddell seam, is a soft coal, which measures eight inches, and has a 30-inch white clay bottom, and a dark bluish-gray shale roof. Number 9, the cap seam, which measures only six inches and has a sandstone roof and bottom, lies directly under the second bluff-forming sandstone.

Kelley coal.—Number 10, the Kelley coal, which is very soft, tender coal that breaks quickly into small cubes, averages 32 inches and is the only coal mined at present. It occurs directly on top of the sandstone just mentioned, and has a sandstone bottom and gray clay roof. It is known especially as a blacksmithing coal.

Number 11, called the Durham or Craven seam, occurs 35 to 40 feet above the Kelley coal. The vein consists of two benches, each from 12 to 18 inches thick, separated by one or two feet of hard shale. The upper bench is somewhat like the Kelley coal, but the lower bench is very rashy. Number 12, the Oak Hill seam, varies from 18 inches to five feet in thickness, and

Digitized by Google

contains a large amount of kidney sulphur. It is about 25 feet above No. 11, and is the topmost seam at this point.

It is thought that the Kelley coal corresponds to the lower Sewanee and Soddy coal, but it may be higher. The seams which are here called by the miners the Dade, Battle Creek, and Whitwell, probably do not correspond to these coals at their type locality.

It is said that there are two thin coal seams which occur below seam No. 1, the Mill Creek vein.

Walden Ridge coal.—The main coals worked on the Ridge proper are called the Soddy, Richland, Angel, Nelson, and Goodrich.

Soddy coal.—The lower Soddy and Richland coals are probably the same, and are thought to correspond to the lowest Sewanee seam. The Soddy coal at Soddy averages 34 inches, but varies from ten feet to nothing. It has no butts or faces, weathers easily, and when washed makes good coke. The roof is of very fossiliferous shale, and the bottom is in places hard, white clay with plant impressions, but where this is wanting, the floor is of sandstone. An average section is as follows:

Blue slate roof	Inches
Rash	3
Coal	32½
Rash or bone	⅛
Soft coal	4
Hard, gray clay, fossiliferous	..
Total	37⅛

The lower 12 inches of the seam contains a very little kidney sulphur, some of which reaches six inches in diameter.

Angel coal.—The Angel coal, which is described under the Tracy City district as occurring at the base of the Sewanee conglomerate, is not worked on the ridge at any point, but is at a horizon that should be carefully prospected, as it may occur in workable thickness.

Nelson seam.—The Nelson seam, which is the next to the lowest coal worked, and the most important of the lower coals, was first mined at Dayton. It occurs in places as one bench, in others as two, separated by a thin parting of bone or clayey

Digitized by Google

shale. It is very soft, in places dirty, and has an average thickness of about 40 inches.

Goodrich coal.—The Goodrich coal, which contains practically no rash or bone, occurs about 30 feet below the Nelson seam, is the lowest coal worked, and averages 24 inches or less in thickness. At places in this district, a coal called the lower Nelson is mined. This occurs about 20 feet below the Nelson seam, and may be the Goodrich bed.

Bledsoe County.—The eastern part of this county lies on Walden Ridge. Along the western edge of the ridge the rocks are upturned, as has already been mentioned, and the coals occur under conditions very unfavorable for mining. The Morgan Springs coal outcrops on top of the Ridge in many places, but it is only locally mined, as it has never been seen with a thickness of more than 24 inches. The outcrop of the Richland coal has been noted in several places, and it is worked locally.

Several coals occur under the Richland outcrop on the side of the ridge, and although these seams have been opened for local use, most of them were soon abandoned, on account of the mashed conditions of the rocks. The remaining part of this county is described on page 170.

Hamilton County.—The western half of this county lies on Walden Ridge and is practically all underlain by good coal. Mines are located every few miles along the eastern escarpment of the ridge. Most of these mines work the Soddy or Richland coal and the lower Nelson seam, and have been in operation for a number of years. At Montlake, the coal mined is probably the Soddy seam, as it lies directly on top of a heavy bluff-forming sandstone, which appears to be identical with the one under the Soddy mines. The coal, which is free from rash and weathers very little, ranges from five feet to thirty inches in thickness, with an average of 36 inches, and often has an inch or two of bone at its base. In places there is a little kidney sulphur in the middle of the seam.

There are several large mines at Soddy, which work the Soddy coal. Data for the type description of the Soddy coal, which is given on page 180 was secured at these mines.

The Sale Creek mines are operated on the lower Nelson seam, which is separated from the upper Nelson coal by 38

Digitized by Google

feet of shale. This lower Nelson may be found to be the same as the Goodrich bed. A section of the coal seam worked is as follows:

Gray-blue shale roof	Inches
Rash	3
Coal, much pyrites	9
Rash	1
Coal, much pyrites	17
Rash	3
Coal, very little sulphur	12
Rash	3
Coal	6
Clay shale bottom	..
Total	54

The average thickness of the coal is 38 inches, and it is used in the making of coke.

The entire western part of this county is underlain by at least two good seams of coal. The upper or Soddy coal is workable in most places, while the lower one, the Nelson, is well developed in the northern half of the county and may be locally mined towards the south.

There are several other seams of coal that occur in this county, but so far none of them have been found workable.

Marion County.—At present all the mining that is being done in the eastern part of this county is at Whiteside, where the New Etna mines are located. The coals that occur at this point have already been described on page 179. The old Etna seam was worked in the past on the McNabb property, situated just across the Tennessee River from the New Etna mines. Some mining was done along the east side of the Sequatchie Valley in this county, but this has all been abandoned. The two main coals are the Kelley seam, which is worked at the New Etna mines, and the Etna seam, which in the past was extensively mined up and down the river. At the time of the Civil War the U. S. Government had some mines located on this seam.

Rhea County.—The western half of Rhea County lies on Walden Ridge and is underlain by several good seams of coal. The ones mined are the Richland or Soddy coal, and the Nelson

Digitized by Google

and Goodrich coals. At present the work is confined to the southern end of the county around the towns of Dayton and Graysville.

The mining at Graysville is on the lower Nelson seam, at which point the coal varies from 10 inches to seven feet in thickness, with an average of 24 inches. It has a slate roof and a hard, sandstone bottom, both of which are very irregular. The thick coal runs in parallel troughs about 150 to 500 feet wide, having a general direction of south 60 degrees west. When the coal in these troughs reaches more than four feet it begins to get dirty.

At Dayton, mines are operated on the Richland and Nelson seams, the main ones being in the Richland coal. This is the first place that the Nelson coal was mined. A detailed description of the mining around this town is given in an article on the coals of the Dayton-Pikeville area, which appeared in Volume I, No. 4, of the *Resources of Tennessee,* and which can be obtained by writing the Tennessee Geological Survey.

At Morgan Springs, situated back on the top of the ridge, the Morgan Springs coal outcrops, showing a thickness of about 24 inches.

In the northeastern part of the county, no mining is done except locally. The rocks that occur here comprise the western side of the Crab Orchard Mountains, and their tilting has been such as to mash the coals badly in many places. At Grand View, coal from one of the upper veins, probably the Soddy, is mined for local use. It is somewhat disturbed. In the past, some mining was done at Roddy, but was abandoned on account of unfavorable conditions of the rocks.

Sequatchie County.—The eastern part of Sequatchie County lies on Walden Ridge. The same conditions prevail in regard to structure, and the occurrence of coal, as in the parts of other counties that lie on the western side of the ridge. The dipping of the rocks back from the valley, and the absence of gorges in which openings could have been made, has prevented any mining in this section of the county.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Digitized by Google

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Maps—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 10 cents.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

Digitized by Google

No. 3—The Power Development at Hale's Bar, by J. A. Switzer, Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Digitized by Google

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

Digitized by Google

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

Vol. V. No. 1—The Hydro-Electric System of Tennessee, by J. A. Switzer.
West Tennessee Gullied Lands and Their Reclamation, by R. S. Maddox.
The White Phosphates of Tennessee, by J. S. Hook.

No. 2—Physiographic Influences in the Development of Tennessee, by L. C. Glenn.
Care and Protection of Forests, by R. S. Maddox.
Two Natural Bridges of the Cumberland Mountains, by Wilbur A. Nelson.

No. 3—The Iron Ore Deposits of Lewis County, Tennessee, by Reese F. Rogers.

No. 4—The Soils of Tennessee, by C. A. Mooers.
Recent Oil Development near Oneida, Scott County, Tennessee, by L. C. Glenn.

Vol. VI. No. 1—Oil and Gas Conditions in the Central Basin of Tennessee, by A. H. Purdue.
Oil and Gas Conditions in the Reelfoot Lake District of Tennessee, by A. H. Purdue.
An Interesting Case of Spontaneous Combustion, by Paul C. Bowers.
Sketch of the Work Done by the State Geological Survey in 1915.

No. 2—Phosphates and Dolomites of Johnson County, by Olaf P. Jenkins.
Structure of the Southern Part of Cumberland County, Tennessee, in Relation to the Possible Occurrence of Oil and Gas, by Charles Butts.
Notes on Manganese in East Tennessee, by A. H. Purdue.

The supply of Vol. 1 No. 2, Vol. III No. 1, and Vol V Nos. 1 and 2 is exhausted.

Digitized by Google

Digitized by Google

OCT 13 1916
UNIV. OF MICH.
LIBRARY

VOLUME VI NUMBER 4

Tennessee. Geological survey

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY AND OCTOBER
BY THE
STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

OCTOBER, 1916

CONTENTS

The Conservation of Phosphate Rock in Tennessee ..... W. C. Phalen
Progress in Reclaiming Waste Lands in West Tennessee ... R. S. Maddox
Publications of the State Geological Survey

Entered as second-class matter January 10, 1913, at the Postoffice at Nashville, Tenn. under the Act of August 24, 1912.

Digitized by Google

Digitized by Google

VOLUME VI NUMBER 4

THE RESOURCES OF TENNESSEE

Published by the State Geological Survey
NASHVILLE, TENNESSEE

OCTOBER, 1916

State Geological Commission

Gov. TOM C. RYE, *Chairman*

DR. BROWN AYRES, *Secretary*
President, University of Tennessee

H. KNOX BRYSON
Commissioner of Agriculture

DR. J. H. KIRKLAND
Chancellor, Vanderbilt University

BISHOP A. W. KNIGHT
Vice-Chancellor, University of the South

R. A. SHIFLETT
Chief Mine Inspector

Geological Corps

A. H. PURDUE
State Geologist

PAUL C. BOWERS
Chemist

J. A. SWITZER
Hydraulic Engineer

R. S. MADDOX
Forester

C. R. WATKINS, JR.
Traverseman

CONTENTS

The Conservation of Phosphate Rock in Tennessee.....W. C. Phalen

Progress in Reclaiming Waste Lands in West Tennessee.....R. S. Maddox

Publications of the State Geological Survey.

Digitized by Google

TN
24
.T2
A4

Digitized by Google

The Conservation of Phosphate Rock in Tennessee[1]

By W. C. Phalen.

INTRODUCTION.

Tennessee today affords a splendid example of what may be accomplished in the conservation of a most valuable mineral resource: namely, phosphate rock.

Before describing specific examples of modern ways and means of conserving phosphate rock, as practiced in the Mount Pleasant, Tennessee, field, a brief description will be given of the position now occupied by that State in this important industry, together with an outline of the occurrence of the phosphate deposits of the State.

TENNESSEE AS A PHOSPHATE ROCK PRODUCER.

The phosphate mining industry in the United States began in 1867, near Charleston, S. C. In Florida, phosphate rock was first actually mined in 1888 or 1889, and the first cargo of Florida rock was shipped in April, 1890. Tennessee rock was first placed on the market in 1894; hence it may be stated that this State has just arrived at man's estate in this important industry. These three States, South Carolina, Florida, and Tennessee, are now producing more than 99½ per cent. of the total phosphate rock marketed for domestic use in and for export from the United States. In 1914, the latest year for which complete statistics are available, Florida produced 78 per cent. of the total production of the United States, South Carolina about 4 per cent., and Tennessee approximately 18 per cent.

From the inception of phosphate mining in the United States, in 1867 to the close of 1914, there was a marketed production of 48,459,406 long tons of phosphate rock in the United States. Of this total, Tennessee furnished 7,850,188 long tons, or 16.2 per cent. of the total.

[1] Published with the permission of the Director of the U. S. Geological Survey.

Digitized by Google

In the following table is given the yearly production of phosphate rock by grades marketed in Tennessee from the beginning of the industry down to the present time.

TABLE I: *Production of phosphate rock in Tennessee, 1894-1914, in long tons. (Marketed product.)*

Year	Brown		Blue		White		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1894	.....	.....	.....	.....	.....	.....	19,188	$ 67,158
1895	.....	.....	.....	.....	.....	.....	38,515	82,160
1896	.....	.....	.....	.....	.....	.....	26,157	57,370
1897	.....	.....	.....	.....	.....	.....	128,723	193,115
1898	.....	.....	.....	.....	.....	.....	308,107	498,392
1899	.....	.....	.....	.....	.....	.....	430,192	1,192,916
1900	.....	.....	.....	.....	.....	.....	454,491	1,328,707
1901	.....	.....	.....	.....	.....	.....	409,653	1,192,090
1902	.....	.....	.....	.....	.....	.....	390,799	1,206,647
1903	.....	.....	.....	.....	.....	.....	460,530	1,543,567
1904	.....	.....	.....	.....	.....	.....	530,571	1,745,054
1905	438,139	$1,509,748	44,031	$121,486	689	$ 2,155	482,859	1,633,389
1906	510,705	2,027,917	35,669	114,997	1,303	5,077	547,677	2,147,991
1907	594,594	2,880,904	38,993	142,382	5,025	24,550	638,612	3,047,836
1908	374,114	1,572,525	79,717	299,941	1,600	4,755	455,431	1,877,221
1909	274,410	1,035,364	66,705	275,165	.....	.....	341,115	1,310,529
1910	329,382 [b]	1,262,279	68,806 [a]	241,071	.....	.....	398,188	1,503,350
1911	365,068	1,450,063	72,302 [a]	263,954	.....	.....	437,370	1,714,017
1912	359,692 [c]	1,420,726	63,639	219,750	.....	.....	423,331	1,640,476
1913	451,559 [c]	1,774,392	(d)	(d)	.....	.....	451,559	1,774,392
1914	483,203 [c]	1,822,770	(d)	(d)	.....	.....	483,203	1,822,770
1915	389,759	1,327,747	(c)	(c)	.....	.....	8,246,030	28,906,894

a. Includes a small quantity of hard rock from Arkansas. c. Includes some blue rock. b. Includes a small quantity of rock from Kentucky. d. Included with brown rock.

OCCURRENCE OF PHOSPHATE ROCK.

There are three important classes of phosphate rock in Tennessee; the white, the blue, and the brown. At the present time, the white deposits, which are known in Perry and Decatur counties, are mined only to a limited extent. The blue rock is being produced but on a small scale in Lewis and Maury counties. The brown rock industry is by far the most important in

Digitized by Google

the State, and extensive operations are now being conducted in the Mount Pleasant field, in Maury County, and also in Giles, Hickman, Lewis, and Sumner counties. The descriptions of conservation methods given in this paper are based on observations made in the Mount Pleasant district in the fall of 1914.

THE WHITE PHOSPHATE ROCK DEPOSITS.

Location.—The white phosphate rock of Middle Tennessee is confined to Decatur and the northern part of Perry counties. It was first observed in the latter county along Toms Creek and shortly after it was also found along other creeks tributary to the Tennessee and Buffalo rivers in the same county: namely, Terrapin and Redbank creeks, flowing into Buffalo River, Spring and Lick creeks south of Toms Creek and on Roan Creek north of Toms Creek flowing into Tennessee River. Later, prospecting revealed its presence west of Tennessee River in Decatur County. The white phosphate rock deposits of Decatur County are found in the Beech River, Rushing Creek, and the Whites Creek districts. The Beech River district includes the Bear and Graham creeks deposits. The Whites Creek district is located to the southeast of the Beech River district, and deposits are known to the north of Beech River, along Cub Creek. In all, nearly 10,000 acres have been prospected in Decatur County along Beech River and Whites Creek. Of all the deposits mined in both Perry and Decatur counties, those along Toms Creek only have proved of any great importance.

Classification.—The white phosphates have been subdivided by C. W. Hayes[1] into three varieties: I, Stony; II, lamellar; and III, brecciated deposits. T. Poole Maynard[2] classifies the white phosphate of the Whites Creek district in Decatur County as lamellar, earthy, and pebble.

The source of the phosphate in the white rock deposits has been considered the phosphatic limestones of the Devonian,

[1] Twenty-first Annual Report, U. S. Geological Survey, Pt. III, pp. 475-485. See also articles by Hayes, Sixteenth Annual Report, U. S. Geological Survey, Pt. IV, pp. 623-630, and Seventeenth Annual Report, U. S. Geological Survey, Pt. II, pp. 536-550.

[2] White rock phosphates of Decatur County, Tenn.; *Resources of Tennessee*, Vol. III, No. 3, p. 167, July, 1913.

Digitized by Google

and the Decatur limestone of Silurian age. It is generally believed that the phosphate rock, as now seen, was formed as late as Tertiary or post-Tertiary time. The deposits of white phosphate, though in no sense stratified, occupy practically horizontal positions. Those in Decatur County, at the top of the Decatur limestone, are contained in pits or crevices, varying in thickness from a few inches up to 20 or 30 feet.

The first, or stony variety, consists of a siliceous skeletons in the form of a horizontal deposit, the cavities in which were originally filled with calcium carbonate which was subsequently replaced by calcium phosphate which now forms about one-third of the rock. This stony phosphate is found in considerable quantity outcropping along the borders of the valley of Terrapin and Redbank creeks, in the northern part of Perry County, associated with chert and cherty limestone probably of Fort Payne age. The replaced siliceous limestone alternates with layers of chert.

The lamellar variety, which is the highest grade, fortunately is the most easily prepared for market and also appears to be the most abundant. Selected specimens of the thin plates contain from 85 to 95 per cent. of calcium phosphate. The greenish material associated with the white and pink plates contains slightly less than 80 per cent. calcium phosphate. This variety appears to have been formed by deposition from solution and is found filling solution channels and cavities in the limestone, and is also found as a matrix cementing augular chert fragments and also as a replacement deposit. In the Beech River district it occurs as a sort of blanket deposit as well as in caves and fissures.

The third variety, the brecciated phosphate, forms most of the surface outcrops in the Toms Creek district. It consists mainly of chert fragments in a calcium phosphate matrix. It is of small importance and it is doubtful whether it exists in large enough quantities to justify development.

On account of the uncertain character of the solution cavities in the limestone, as will be noted from the descriptions given above, and from the origin postulated below, it will be seen that little can be stated positively with reference to the shape, extent, and size of individual deposits. As Maynard[1]

[1] Loc. cit., p. 163.

Digitized by Google

has stated with reference to the Decatur County deposits, they are so variable in thickness, width, and areal extent that it is impossible to determine tonnages, with any degree of accuracy. Great uncertainty exists with reference to extent and size of individual deposits and careful prospecting must be done, which is expensive.

Origin.—All the varieties may have been formed by accumulation from percolating and flowing underground waters, as was first pointed out by Hayes, the deposition having taken place under hydraulic pressure. As J. S. Hook says, "that the white rock phosphates were deposited from percolating solutions, there can be no question."[1] Maynard[2] observes, however that in the case of the Beech River and Rushing Creek tracts in Decatur County, Tenn., "the continuity of the deposits suggests that influences other than those mentioned by Hayes have played a part in the origin of these deposits," and from the fact that the Devonian has been reduced to but a fraction of its original thickness, he points out that part of the white rock may have been formed when the limestone was subjected to subaerial erosion and subsequently enlarged by the removal of limestone in solution. From the origin postulated the deposits can not be expected to extend to considerable depths.

Methods of mining and preparation.—The Tennessee white rock phosphate deposits have been mined by both the open cut and by tunnelling. The former usually being the cheaper has been employed wherever the overburden was not thick or of such a nature that it could not be removed inexpensively. Where tunnelling has been used in mining the lamellar rock, the phosphate rock disseminated in the overburden has been lost, but there is also some loss connected with open cut mining. The brecciated and stony varieties, as already stated, are low grade and have not been considered worth mining. As pointed out by Hayes, however, analyses of the matrix associated with the brecciated deposits show it to be high grade and, when carefully separated from the associated chert, may contain as much as 80 per cent. of calcium phosphate. The ordinary

[1] *Resources of Tenn.*, Vol. V, No. 1, p. 31.

[2] Maynard, T. Poole, white rock phosphate deposits of Decatur County, Tenn.: *Resources of Tennessee*, Vol. III, No. 3, pp. 161-169, July, 1913.

Digitized by Google

matrix and chert together contain about 40 per cent. of phosphate, which is too low to be utilized at the present time. The matrix is rather soft and crumbles readily to powder when the rock is crushed. On the other hand, the chert is harder and breaks into fragments without shattering or crumbling. For this reason, Hayes suggests the possibility of separating the phosphate rock by crushing and screening out the chert.

Still another method of raising the grade of white phosphate is to grind and wash it after the manner employed with the brown rock phosphates of the Mount Pleasant field. The quantity of material in any given locality must be carefully ascertained before this is done to avoid installations that are more complex and costly than the quantity of ore in any given district appears to justify. Some of the lamellar rock has been shipped to fertilizer manufacturers without any treatment. No work, so far as known, is now being done on a commercial scale in any of the white phosphate rock deposits.

THE BLUE PHOSPHATE ROCK DEPOSITS.

Location.—The blue phosphate rock deposits of Tennessee occur mainly in Hickman, Lewis, and Maury counties, and are now being mined by the Charleston, S. C., Mining & Manufacturing Co., at Gordonsburg, Lewis County, and the American Fertilizer Company at Leatherwood, Maury County. Deposits have also been reported from Wayne, Perry, and Williamson counties. With the exception of small areas on Leatherwood Creek and its tributaries in both Maury and Hickman counties; an area to the west of Tucker's Bend on Duck River; and a small area to the south of Centerville, in Hickman County, the principal workable deposits of blue rock thus far discovered occur on both sides of the lower part of Swan Creek, in Hickman County, and the upper part of Swan Creek, in Lewis County, where there occur small areas in which the blue phosphate bed is of workable thickness; i. e., 24 inches thick or more and of high grade. Eastward from near the mouth of Little Swan Creek the thickness of the phosphate bed increases abruptly and in places it is as much as 30 inches thick, as at the Mayfield mines of the Charleston, S. C., Mining & Manufacturing Co., at Gordonsburg.

Digitized by Google

In the northwest part of Maury County, blue rock is known in the vicinity of Leatherwood, where it is now being mined by the American Fertilizer Company. Though known for some time, this deposit was not worked until the railroad line was built along Leiper's Creek. The deposit extends along the Dry Prong of Leatherwood Creek, keeping to the north of these waterways. Blue rock is also known along Cathey's Creek, Baptist and Love branches.

In general, it may be stated that the blue rock is only locally developed and may thicken and thin within a short distance even in those localities where the thickest and best rock is found.

Classification.—All the blue phosphate rock deposits are of Devonian age and are the original constituents of a stratigraphic series. In other words, they were deposited or laid down in the position in which they are now found. The chief change and practically the only one which they have undergone is that of consolidation. C. W. Hayes[1] has divided the blue phosphate rock, which he originally described as black bedded phosphate, into four different classes as follows: Oölitic, compact, conglomeratic, and shaly phosphate. Of these, the oöltic and the compact varieties, together with the nodular variety in the green shales occurring at the top of the Devonian, embrace the high grade material, or that which contains locally 70 per cent. and more calcium phosphate.

Origin.—The original source of the phosphate contained in these beds will not be considered in detail in this place, but it seems probable, as pointed out by Hayes[2], that some of the material came from the phosphatic residuum resulting from the decay of the Ordovician limestones. Such phosphate is secondary. Some of the phosphate was supplied by phosphatic organisms living during Devonian time and is, therefore, primary. It seems more than likely that the sorting action of the sea water must have played a part in concentrating what may have been generally broadly distributed low grade deposits into localized and high grade deposits, such as those now found.

---

[1] Seventeenth Annual Report, U. S. Geol. Surv., pt. II, 1896, pp. 519, and 525-527.

[2] Seventeenth Annual Report, U. S. Geol. Surv., pt. II, pp. 534-535; U. S. Geol. Surv. Folio, No. 90, p. 6, 1903. See also Hook, J. S., *Resources of Tennessee*, Vol. IV, No. 2, pp. 77-80. April, 1914.

Digitized by Google

Mining and preparation.—The ore is first stripped around the outcrops of the hill to a distance of 20 to 25 feet, leaving an exposed face of rock of about the same thickness. When the overburden becomes too heavy, surface-stripping has to give place to regular underground mining. The methods of mining blue rock may be briefly outlined as follows: Main entries are run into the hill at regular distances of 400 feet apart. After leaving a 50 foot pillar at the outcrop to support the roof, rooms are turned from the entries at alternating distances of 50 and 36 feet apart. Side entries, 12 feet wide, are carried in 20 feet and then the rooms proper, referred to above, are mined. This makes a room 50 feet wide. The rooms are carried forward 200 feet, thus meeting the operations carried back the same distance from the next main entry. Mining is carried back on the pillars, which are 36 feet wide. In this way mining may be carried forward to the limits of the property.

A so-called mining streak of soft dark shale is first removed from the roof of the phosphate bed and the latter is then loosened by being shot up from the floor with dynamite. It is then loaded into trams and hauled to the works, where it is crushed, dried, and separated into the different marketed sizes. No washing is necessary as in the case of brown rock.

Composition.—Some of the blue rock is of very high grade, containing as much as 81 per cent. of tri-calcium phosphate. High grade rock of this class is, however, exceptional and the blue rock now shipped does not run much more than 75 per cent. tri-calcium phosphate and will probably average between 70 and 75 per cent. The analyses of samples of blue rock collected on the upper part of Swan Creek and at the head of Baptist Branch are given below:

Analyses of Blue Phosphate Rock.

[W. C. Wheeler, U. S. Geological Survey, Analyst.]

	Per cent. P_2O_5	Per cent. $Ca_3(PO_4)_2$
No. 57	33.40	72.98
No. 58	33.10	72.33
No. 60	33.58	73.36
No. 61	33.36	72.90
No. 62	31.66	69.20

Digitized by Google

No. 57: Mayfield Mine.—Charleston, S. C., Mining & Manufacturing Co., Gordonsburg, Lewis Co., Tenn. Sample of blue rock from short room in Tank Hi[illegible]ings.

No. 58: Mayfield Mine.—Charleston, S. C., Mining & Manufacturing Co., Gordonsburg, Lewis Co., Tenn. Sample of blue rock from Pine Tree No. 2 entry.

No. 60: E. D. Hughes, head of Baptist Branch, Maury Co., Tenn.

No. 61: E. D. Hughes, head of Baptist Branch, Maury Co., Tenn.

No. 62: Mayfield Mine, Charleston, S. C., Mining & Manufacturing Co., Gordonsburg, Lewis Co., Tenn. Ground blue rock.

THE BROWN PHOSPHATE ROCK DEPOSITS.

Location.—During 1914 brown phosphate rock was mined in Maury, Giles, Hickman, Lewis, and Sumner counties, Tenn. The district in the vicinity of Mount Pleasant, Maury County, contains the most extensive deposits yet discovered in this State, and here are located the major operations on the brown rock deposits. This district is of irregular shape but is approximately 4 or 5 miles long, extending both north and south of the town limits and into the hills to the east. During 1914, at least 10 companies were active in the vicinity of Mount Pleasant. To the southeast, at Scott's Mill, and Southport, are located deposits of a different type from the greater part of those exploited in the immediate vicinity of Mount Pleasant. They are in the nature of "hat band", "rim", or "collar" deposits, while those near Mount Pleasant are of the "blanket" type, terms which will be subsequently explained. Along the Columbia and Williamsport pike, six to eight miles northwest of Columbia; on Duck River between Alexander and Roberts bends, and also near Parson's Bend, are deposits of brown rock, while others are scattered over the country in the vicinity of Columbia, Maury County. In the Century or Harlan district, about 7 miles northwest of Columbia, are the extensive and important mines of the Federal Chemical Company, which are being worked on a large scale at the present time.

In Hickman and Lewis counties, brown rock deposits have been developed in the same general regions where the blue rock has been or is now worked. Thus brown rock occurs on Indian Creek, between Dean's Station and Centerville; on Duck River to the east of Centerville, and near the mouth of Swan Creek. Brown rock also occurs almost immediately below the blue

Digitized by Google

rock and is now being mined near the Mayfield mines of the Charleston, S. C., Mining & Manufacturing Co., at Gordonsburg.

To the north of Pulaski, the county seat of Giles County, brown rock is shipped from the mines along Pigeon Roost and Richland creeks. Two companies operated here in 1914: namely, the American Phosphate Mining Company, and the Charleston, S. C., Mining & Manufacturing Co. Both the blanket and hat band or rim type deposits occur in this district.

In Sumner County brown rock is being mined in the vicinity of Woodson, and in the past years, it has been mined in Davidson County.

Classification.—The brown phosphate rock deposits occur at several horizons associated with the limestones of the Ordovician period. Phosphate rock in different formations is scattered throughout a large part of Middle Tennessee, as is indicated by the descriptions of the distribution given above. The rock is porous, not very coherent, and occurs in plates, varying in thickness from a fraction of an inch upwards separated by partings containing clay, which is generally of a looser and quite different texture from the massive rock itself. The massive rock is referred to as lump, plate, or hard rock. Sometimes the brown rock is quite thick and detached masses weighing several hundred pounds have been found. The clay partings, which occur within and below the brown rock, are referred to as muck and constitute somewhat low grade rock. Considerable true sand phosphate is found associated with both the lump rock and muck.

The deposits, depending upon their manner of occurrence, have been designated by Hayes[1] as "blanket" and "collar" deposits. The latter are also known as "hat band" or "rim" deposits. The names suggest the character of the formation. The term "blanket" applies to the nearly horizontal deposits of considerable areal extent, while those designated "hat band" or "rim", occur within a limited vertical zone on the hillsides. The blanket deposits occur on a notable scale in the vicinity of Mount Pleasant and are found in the Century and the Giles and Sumner county districts. Good examples of collar or rim de-

[1] U. S. Geological Survey Folio, No. 95, 1903, pp. 5 and 6.

Digitized by Google

posits are found in the vicinity of Southport and Scott's Mill. The form of the deposits depends upon the topography or lay of the land, and it is obvious that the blanket deposits are the most extensive and hence the most valuable.

Origin.—The phosphatic material was deposited originally on the floor of a shallow sea, in which flourished phosphate secreting organisms. Without doubt, a great deal of calcareous material was deposited with the phosphate, forming phosphatic

FIG. 1. Limestone "horses" associated with collar deposit; Tenn.-Ark. Phosphate Company, Scotts Mill, Maury County, Tenn. (W. C. F.)

limestones, and the phosphate rock, as it now occurs, is the result of leaching the calcareous parts of the original rock. As a result of this leaching, the disseminated phosphate has been concentrated as the calcareous parts have been dissolved away, and there has resulted a high grade phosphatic deposit from what was a low grade or lean material. In other words, the brown phosphate, as it occurs today, represents a clear case of secondary concentration with possibly some secondary enrichment.

Digitized by Google

Where the process of solution, which has resulted in the removal of the limestone layers and the disseminated lime carbonate and the concentration of the phosphate rock, has been more or less incomplete, limestone "horses", so-called, are left, and, where it is most advanced, as along the courses of the original joint planes, the deepest deposits of phosphate, known as "cutters", or "dips", are found. The irregularities of the underlying rock surface and the manner in which the phos-

FIG. 2. Brown phosphate deposits arching over limestone horses. Charleston, S. C., Mining & Manufacturing Co., Mt. Pleasant, Tenn. (W. C. F.)

phate settles down on it have given rise to the undulations which occur in the phosphate rock deposits. (See Fig. 2.) The intervening clay layers, associated with the phosphate rock, represent the original beds of non-phosphatic but clay-bearing limestone. This material is commonly referred to as muck. Disseminated phosphatic sand is associated with both the plate, lump or hard rock, and with the muck.

Digitized by Google

CONSERVATION OF TENNESSEE PHOSPHATE ROCK.

General statement.—There is going on in the Mount Pleasant phosphate field at the present time and, without doubt, in other parts of the Tennessee brown rock phosphate areas, changes in methods of mining and preparation of phosphate rock that will result in leaving very little or no wasted phosphate in the ground. Some phosphate is going into the waste ponds but the time will without doubt come when all this material will be reworked and even now some companies are working or are planning to work the old tailings. The mining and milling methods of the last decade are revolutionizing the industry and incidentally conserving this valuable fertilizer material. They are in striking contrast with the crude and wasteful methods formerly employed in the brown rock field.

When phosphate was first mined in this region, it is safe to say that at least half of the good material, such for example, as is now being worked, was thrown away. A great deal of this rejected material can not in the nature of things be recovered; for in the course of time it has become so thoroughly mixed with clay and in places so covered with overburden as to make it impossible to work it at a profit. Though the large operators are using up-to-date methods, even now some of the small operators are employing the old-fashioned hand methods which in the past resulted in the loss of much valuable rock.

The object, of course, in preparing phosphate rock for market is to remove as much of the clay, chert, and limestone as possible from it. Theoretically it is possible to remove all these impurities, but this is not practicable, especially in the case of the clay. There is no sharp division between the finest phosphate "sand" and the clay, and it would obviously be wasteful to carry the process of obtaining the fine "sand" beyond the point where the cost would offset the value of phosphate obtained. This is one of the practical considerations connected with the modern conservation of phosphate rock which perhaps has not always been given just and deserved consideration.

The point beyond which it is not practicable to carry the preparatory treatment is not fixed and standards vary from time to time and probably at a given time among individuals

Digitized by Google

and corporations. Thus in the phosphate mining industry, as practiced in Tennessee in the early 90's, rock was discarded which has a high value today, and the former apparent lapses from the highest standards have in the course of time proved to be not lapses at all, but simply conditions imposed by the trade and the times. In other words, the phosphate once discarded is now being utilized. The open cut or surface method of mining brown rock, as practiced in the Tennessee field, with which the writer is more especially familiar, are peculiar in this respect, and the generalizations made do not cover many other classes of mining and certainly will not apply to underground mining in general.

GRADES OF COMMERCIAL BROWN PHOSPHATE ROCK.

Most of the rock from the Mount Pleasant field is shipped in three grades: namely, those containing 72, 75, and 78 per cent. of calcium phosphate. Five per cent. of iron oxide and alumina is the maximum allowed and this is usually referred to as "I and A" in the trade and in commercial analyses. At one time only 78 per cent. rock was shipped from the Mount Pleasant field and rock of this grade is still known as export rock. The guaranteed content in phosphate of lime, "bone phosphate", or "B. P. L.", as it is commonly referred to in the trade, next fell to 75 per cent. and at the present time many of the companies are finding it difficult to ship this grade exclusively, and the life of the 75 per cent. rock is limited. Every per cent. of iron oxide and alumina less than the 5 per cent limit is regarded as equivalent to an additional 2 per cent. of calcium phosphate for it is considered that in the subsequent treatment of the phosphate in the manufacture of fertilizers, the harmful effect of 1 per cent. of iron oxide and alumina offsets the beneficial effect of 2 per cent. of calcium phosphate. If there is more than 5 per cent, of iron oxide and alumina, the superphosphate becomes gummy and farmers find it difficult to drill it into the land.

PREPARATION OF PHOSPHATE ROCK FOR MARKET, WITH PHASES OF CONSERVATION INVOLVED.

There are many stages to be considered under the heading of preparation of phosphate rock for market, but they may all

Digitized by Google

be subdivided into three major operations as follows: (1) Removal of overburden; (2) mining; and (3) washing, in which is included drying. The present methods of utilizing and thus conserving (protecting from loss) the brown phosphate rock supplies, especially in the Mount Pleasant field, naturally are included under the above headings and therefore will be described in connection with them so far as this can be done.

Removal of overburden.—The overburden of the brown rock in the Mount Pleasant field consists chiefly of clay and varies from 1 foot to 30 feet. Usually it is less than 20 feet;

FIG. 3. Removing overburden by means of drag line, Mt. Pleasant, Tenn. (J. S. Hook.)

a thickness of 30 feet is excessive in those places where mining is now in progress. The methods of removal of overburden are diverse. Under exceptional conditions the old time crude and expensive hand methods have to be resorted to, but in most places, and especially where virgin ground is being opened, operations are conducted in the most up-to-date fashion. (See Fig. 3.) Where the overburden is not very thick or hard, it may simply be plowed up and removed with scra-

Digitized by Google

pers or it may be loosened with dynamite and then removed with scrapers. A favorite method of getting rid of the overburden, used especially in ground that is being reworked, is to first "hog" or undercut it, pry it off with bars, and then scrape or carry it away.

The drag line excavator and the steam shovel are types of up-to-date machinery used in removing overburden in this field. The hydraulic method is also used. Both the overburden and the rock itself are removed by this last named method, which is simplicity itself in action and which requires a minimum of

FIG. 4. Mining phosphate by the hydraulic method. (J. S. Hook.)

labor in operation: namely, one man to handle the hydraulic gun and two to keep the sluices clear. As practised at the plant of the Blue Grass Phosphate Company, in the southern part of the Mount Pleasant field, the rock is mined out in small areas and the overburden from one area is washed into the mined-out cavity next to it. The resultant topography is level and may be farmed over. According to this method of removing overburden the land is conserved for farming purposes for future generations and indeed greatly improved, for the phosphate sand and rock, formerly below the subsoil is thoroughly

Digitized by Google

incorporated in the soil and the fertilizing value of the phosphate thus rendered available.

Methods of mining.—Much of the mining in the Mount Pleasant field has to be done by hand on account of the method of occurrence of the brown rock. The steam shovel has not proved successful because it can not discriminate as to grade of ore mined, with the result that much clay and flint get into the product, which has to be subsequently removed. The cantilever adjunct to mining, which is employed at the plant of the Hoover & Mason Phosphate Co., is unique, there being only one in this field. The hydraulic method of mining is used at two plants and has many advantages, as pointed out under the preceding topic. These mechanical methods of mining and removing overburden, which have cheapened operating costs, have played the major part in conserving Tennessee brown rock.

Reworking deposits.—The mode of occurrence of brown phosphate rock has been pointed out, and its blanket form, together with the deep cutters projecting like a network of roots as it were from this blanket into the underlying limestone, has been described. In the early days of mining, all the phosphate rock occurring between the limestone "horses" was left, owing to the difficulty in mining it. Moreover nearly everything that went through the tines of a phosphate fork or a two-inch screen was discarded. The latter material for this reason has come to be known as "screenings" or "throwbacks" and at certain plants this is now being worked. The screenings or throwbacks can be easily distinguished from the normally occurring plate or lump rock by its heterogeneous appearance, the lump rock being scattered throughout the mass. From the fact that the "throwbacks" represent material which has been worked over and the larger lump rock removed, it follows that the proportion of muck, sand, and clay in it is larger than in unworked territory. On the Ruhm Phosphate Company's property, in the northeastern part of the Mount Pleasant field, the worked-over phosphate deposits are located on one of the terraces that surround the town. This location at the top of a hill is such that the ore can be handled easily by gravity and the hydraulic method of mining is therefore employed. The

Digitized by Google

rock appears practically at the surface in quantity and in addition to the muck left from early operations it is loaded with small lump rock, discarded in the days of early mining. As hydraulicking is practised here, the limestone horses are often in the way and have to be blasted out, but this is not difficult owing to the loose or platy character of the phosphatic limestone associated with the brown rock deposits.

In addition to the hydraulic method, which can be employed only in certain favorable locations, hand mining is also employed. Where hand mining is practiced, the ore is usually screened on the spot where the miner is at work. The fine material passes through the screen and is saved and washed; and the coarse rock, which is left, is hauled away and dried by burning on ricks of wood in the open, thus saving rehandling in the mill. The lump rock, as mined, usually contains from 20 to 21 per cent. of moisture, and drying it in this way reduces the moisture to one per cent. or less. In certain places where mining with the hydraulic giant is not practicable or where the giant fails to get all the rock, hand mining has to be resorted to and thus literally the ground may be gone over the third time in order that no phosphate rock shall be lost.

At the Century plant of the Federal Chemical Company, on the Williamsport Pike, northwest of Columbia, screenings are now being worked on an extensive scale.

The following analyses show the content in phosphoric acid and phosphate of lime of material left in earlier mining operations but which is now being worked at the plants mentioned above. It is certain that these analyses are in general below the standard in phosphate content of a great deal of the material which is being reworked in this field. It is doubtful whether any hand sample can adequately represent the normal content in calcium phosphate of the material which is now being reworked, owing to the difficulty of properly apportioning the lump rock and the muck. It is more than likely, however, that very low grade material can and will be profitably worked provided some of the cheaper methods of operating can be brought to bear upon it. There is also given in the following table, an analysis of a sample of phosphate muck. This material is found in larger proportion in the throwbacks than in the normally occurring rock, for the reason that in the original

Digitized by Google

mining operations only the lump rock was saved. The writer has been told that the recovery of the phosphate in the muck handled is about 50 per cent. on the wet basis and about 40 per cent. on the dry, assuming that there is from 20 to 21 per cent. of moisture present. Unless the muck runs well up in calcium phosphate, it hardly pays to handle it:

Analyses of brown and muck phosphate from reworked deposits, Maury Co., Tenn.

(W. C. Wheeler, Analyst.)

	Per cent. P_2O_5	Per cent. $Ca_3(PO_4)_2$
No. 2	21.16	46.24
No. 27	31.88	69.66
No. 37	20.13	43.98
No. 38	27.31	59.69

No. 2: Phosphate muck from 2' layer; Hoover & Mason Phosphate Co.
No. 27: Throwbacks or material reworked 5 feet thick; Federal Chemical Company, Century plant.
No. 37: Material reworked. Average thickness, 4 feet, where sample was collected. Ruhm Phosphate Mining Company.
No. 38: Material reworked. Average thickness, 4 feet, where sample was collected. Ruhm Phosphate Mining Company.

Reworking cutters.—The meaning of the term "cutters" has been given and the fact that the phosphate rock in them was left unmined in the early days of mining has been pointed out. The development of the cutters,* which took place along original joint planes, varies greatly within the restricted Mount Pleasant field. In some places, notably south of Mount Pleasant, on the Hoover and Mason property, they are of large size. Some were observed 30 to 35 feet wide and as much as 20 to 25 feet deep, averaging probably 18 feet to 20 feet in depth. In these abnormally wide and deep cutters, it is not uncommon to have small limestone horses. A short distance away from the Hoover and Mason Company's property, some of the cutters are so narrow that the phosphate rock in them can be removed only with difficulty.

Hand methods of mining have to be employed almost exclusively to remove the phosphate rock from these cutters, owing

*The origin of cutters has been shown by Mr. J. S. Hook. *Res. of Tenn.*, Vol. IV, No. 2, p. 64.

Digitized by Google

to the peculiar character of its occurrence. Hydraulic methods are employed, as is the case in the Hickman County field where the depth of the cutters is also great. Owing to the depth of the cutters the work has been done in benches of convenient height for the miners. The ore is picked out and shoveled from bench to bench and finally into wagons, in which it is hauled to the mills. Mining the deep cutters is usually carried on in fair weather or when the roads are good. In working over virgin ground at the present time, the rock in the cutters is readily and cheaply obtained by the cantilever method in use at the Hoover and Mason plant.

Territory formerly worked over is again being worked at the Arrow mine of the Charleston, S. C., Mining & Manufacturing Co. Most of this work is in rather shallow cutters. The material is picked out and screened either on the tines of a phosphate fork or on a small movable one-inch mesh screen. The coarse rock is dried or burned on ricks of wood; the muck is washed at the company's mill. The old cutters containing phosphate rock are located by hand prospecting with a long sharp steel rod.

Washing and drying.—The washing processes whereby the mined rock is freed from clay, chert, and limestone are elaborate, and the mills in which the work is done are, for the most part, large and modern. These modern washing plants, which have done so much to make the mining of low grade rock in this field profitable and which, therefore, are playing such an important role in the conservation of phosphate rock in Tennessee, have practically all been installed during the last decade. The principles of the washing processes are identical throughout, but the details of manipulation differ at the different plants. The phosphate rock, as mined, is brought to the washer either in wagons or by tram. Where hydraulic mining is practised, it goes to the plant through a flume. The material mixed with water is delivered into a hopper at the top of the mill and the subsequent operations, for the most part, are conducted by gravity. From the hopper the rock passes through a toothed revolving crusher and then into log washers. From the washers it passes to a perforated cylindrical or conical screen. The coarse or lump rock, which fails to pass

Digitized by Google

through the screen, passes on to a picking belt where limestone and chert fragments and clay balls are removed. The material then goes to the wet storage sheds or piles to be dried later. The fine material may go through a settler or clarifier provided with riffles, or through several settling tanks in succession in which the sand settles out. The clay and sand not caught in the process goes to the waste ponds. The above descriptions briefly outline the fundamentals of the washing process as carried on at most of the plants, but, of course, as has been mentioned, details are widely divergent.

The clay and the phosphate sand which passes to the waste ponds are of great interest in the problem of conservation. When the material reaches the waste pond, the coarse sand settles out first and naturally nearest the end of the waste pipe or flume. This material is the highest in calcium phosphate. It is planned to rework material of this character at one of the plants near Mount Pleasant and already at another the old tailing dumps are being worked. At this plant much attention has been paid to the process of separating the clay and phosphate sand.

There is a washer at this particular plant which differs from any other in the field and is most thorough in its action. The clay resulting from the action of this washer was observed in the waste pond. It had been in suspension for a long period and material taken and rubbed between the fingers appeared almost of impalpable fineness. Some of the phosphate sand from this washing process is so fine in texture that it sifts through the meshes of the sacks in which it is shipped. The analyses of material obtained from some of these waste ponds, together with those of material from ponds abandoned years ago, but which are either being worked or which it is planned to work are given below. It has been suggested that the material in these waste ponds might be used in its present form on Tennessee farms, but this has been found impracticable as it will not bear the cost of transportation. The high phosphate content in certain of the samples collected is noteworthy.

Drying is accomplished in two very different ways which are representative of the old and new methods employed in the Tennessee brown phosphate field. At nearly all the large plants modern rotating cylindrical driers, similar to rotary

Digitized by Google

cement kilns, are in use, but the rock is fed both at the hot and cold ends. It would seem that the latter method would be the more efficient. There is generally some special advantage when the old-fashioned method of drying on wood ricks is employed and where it is in use it generally saves either additional handling or haulage. Drying generally reduces the moisture present from 20 to 21 per cent.:

FIG. 5. Rotary kiln dryer, Mt. Pleasant, Tenn. (J. S. Hook.)

Analyses of waste material from phosphate washers in the Mount Pleasant, Tenn., phosphate field.[1]

(W. C. Wheeler, Analyst.)

	Per cent. P_2O_5	Per cent. $Ca_3(PO_4)_2$
No. 13	31.79	69.47
No. 20	27.20	59.44
No. 25	29.91	65.34
No. 32	20.38	44.53
No. 36	14.36	31.37
No. 42	30.63	66.92
No. 47	20.71	45.26
No. 50	28.59	62.47
No. 54	26.50	57.90

[1] Some of this material is now being worked and some of it will soon be worked.

Digitized by Google

No. 13: Sample of material from waste pond; International Agricultural Corporation, Frierson Plant.
No. 20: Sample of material formerly discarded but now being reworked; Federal Chemical Company, Tennessee Plant.
No. 25: Sample of material from waste pond; Tenn.-Ark. Mining Company.
No. 32: Sample of material from waste pond, near outlet of waste pipe. It is planned to rework this. Federal Chemical Co., Century Plant.
No. 36: Sample of material from waste pond; Ruhm Phosphate Mining Company.
No. 42: Sample of material from waste pond; International Agricultural Corporation, Jackson Plant.
No. 47: Sample of material from waste pond; Blue Grass Phosphate Company.
No. 50: Sample of material from waste pond; Hoover & Mason Phosphate Company.
No. 54: Sample of material from waste pond; Charleston, S. C., Mining & Manufacturing Company.

CONSERVATION OF FINES.

In drying phosphate rock, much material in finely divided form has been lost by being carried out through the flue, owing to the powerful drafts employed, especially in the modern types of driers. At many of the plants steps have been taken to save this material. This is accomplished by means of bends in the flue or by hoods or baffles. The following is an analysis of fine material caught and saved at the Century plant of the Federal Chemical Company:

Sample of finely divided phosphate sand caught in chimney.
(W. C. Wheeler, Analyst.)

	Per cent. P_2O_5	Per cent. $Ca_3(PO_4)_2$
No. 35	30.29	66.19

Phosphatic limestone as a source of phosphate.—Directly below the phosphate rock horizon occurs the phosphatic limestone from which the brown rock itself has been derived. This is often platy in structure, plates of highly phosphatic material alternating with the nearly pure calcareous layers. This platy or laminated structure is original and throws light on the origin of the brown rock itself, which also occurs in plates separated by layers of muck, clay, and sand, the former corresponding to original layers of phosphatic limestone, and the

Digitized by Google

latter to the intermediate clayey and less phosphatic limestone layers. There must be an enormous tonnage of this phosphatic limestone scattered throughout the phosphate rock areas of Middle Tennessee. A long period must elapse before any attention will be given to this comparatively low grade material as a source of phosphate, but it would be hazardous to say that this will never be done. Of course, in the mined-over area much of the richer limestone has been covered so deeply, as a result of stripping the phosphate beds, that it will be difficult and expensive to get at it. The results of analyses of this limestone, some of which was in a leached and some in a partially leached condition, occurring in horses between cutters, show calcium phosphate ranging from four to more than forty-two per cent. The carbonate and the phosphate of lime mixture in this material has considerable value as fertilizer when applied directly to the land in finely pulverized form, and, although it is difficult to predict how and when this material will be utilized, it seems fairly certain that it will prove of value at some future time.

Digitized by Google

Progress in Reclaiming Waste Lands in West Tennessee

By R. S. Maddox,
Forester of the State Geological Survey.

In West Tennessee some of the most improved implements for cultivating and harvesting crops are being used. The most approved way of preparing the land for crop production is being employed—deep plowing and shallow cultivation. The silo has been introduced. The importance and value of the work of the farm demonstrator is becoming more apparent all the time. Farmers' meetings are held where discussions relative to the farm are carried on. Here agricultural educators speak on the different phases of farming and stock raising. Recognition of a need for more productive farming—better crops, better horses, cattle, sheep and hogs—is growing everywhere. These facts point to one thing, progress. The West Tennessee farmers are progressing. The old fashioned way of doing things is yielding before the advance of new ideas, and many of the land owners are taking advantage of the latest scientific methods.

The West Tennessee farmer's spirit toward the reclamation of his waste land further illustrates this same attitude. It is becoming more and more recognized that in order to get the most from the farm it must be cared for, that waste must be stopped and rebuilding started. While talking over waste land problems with landowners who have not yet begun restoring their property, the writer is frequently informed by them that they must do something, for if they do not act, both their land and timber will soon be gone. Already experiments have been undertaken and a good many farms are being reclaimed under the direction of the Forestry division of this Survey, while others are to be worked upon in the near future.

In formulating a plan for restoring the West Tennessee waste lands, it was necessary to know first the approximate boundary and acreage of the section containing such lands. With this in view, the writer, with horse and buggy, made a

Digitized by Google

circuit around the area embracing as nearly as he could determine, the territory supposedly containing the waste lands, and secured additional information of its extent by inquiring from men along the route.

While making this general circuit, the idea was kept steadily in mind of getting acquainted with as many landowners as possible along the route and of making them acquainted with the aims of the undertaking.

FIG. 1. Badly eroded land, once cultivated. Madison County.

In the fall of 1914, the writer estimated* these waste lands, in the aggregate, at between 200,000 and 300,000 acres, and now, after a more careful study, there is no reason to reduce the estimate.

The second tour of the area was begun in January, 1915, and much more time was necessary in making each of the second and third trips than the first, because not only were the same men visited as in the first, but others. The landowners were approached right at their homes, in the belief that on the ground is the place to tackle such a problem. The nature and aim of the work could be by this means more thoroughly discussed and understood. Besides the men visited, a list of names of farmers was secured and to these were mailed copies

*_The Resources of Tennessee_, Volume V, No. 1, January, 1915.

Digitized by Google

of the *Resources of Tennessee* containing the article on the reclamation of West Tennessee's waste land. In this way a number of men became more or less acquainted with the undertaking before they were visited and the work talked over with them. The men seen in their homes named other men who would be interested and thus there was a definite branching out from the first route traveled. Consequently as these men were approached the work kept expanding. All the men were not only friendly but were apparently interested, and many were enthusiastically so.

Another phase of the undertaking has been speaking to the farmers at various meetings, and to the children at different

FIG. 2. Black locusts have stopped gullies and made post timber. Hardeman County.

schools. The boys and girls of today will after a while have the ownership of the land and it is their right, *now*, to know whatever they may of the importance of caring for this land. In speaking at different meetings the object was to reach as many men at a time as possible. Sometimes the writer was invited to attend certain meetings and speak on reclamation. Sometimes he heard of gatherings where agricultural subjects were to be discussed, and joined in the general program for the day. At these meetings he put forward the scheme for a general reclamation project and when possible invited a dis-

Digitized by Google

cussion on the part of the farmers. Many interesting points were brought out in these discussions. One landowner would speak of the value of the walnut tree; another would mention the worth and also the scarcity of the yellow poplar. Many men spoke of the excellence of the black locust for posts; and some who used to spend time trying to destroy it are now preserving it and setting out more. Some would comment upon other growths recommended. All this discussion emphasized the points which had been dwelt upon in the general reclamation scheme: namely, to restore land by the use of vegetation that when mature will be of value either for use at home or for revenue.

One of the most interesting phases of the work has been the part taken by the farmers with the writer in doing the real reclaiming of their land. Last summer he went to a number of farmers and proposed to go and personally help them make a start. Men like to see some of the things done that are talked about. As a result to date—September, 1916—many experiments have been undertaken in this manner. Fifteen farmers in Henry, Carroll, Weakley, Henderson, and Madison counties used the brush dam method. They took teams at different times and with enough other men to help, cut down and dragged bushes, saplings, and trees to their gullies, and the writer with some assistance trimmed off the limbs and built dams. The process did not consist merely in trimming and dumping the brush into the gully in a helter-skelter sort of way; but the limbs were piled closely. Usually when starting the dams, the tops of the limbs were laid down stream for several layers to prevent slipping under a heavy flow of water. Then the greater part of the rest of the dam was built with limbs laid crosswise so the stream flow will strike them perpendicularly. In this way the mud and sand are better caught than when they flow along the branches lengthwise. Occasionally, as the dam progresses limbs are piled with tops upstream so as to tie the brush more securely together. As each dam was built, the body of the saplings or small trees, after being trimmed, were cut into convenient lengths and placed on the dam to hold it more closely together and to make it secure and lasting.

Digitized by Google

Right here the fact should be emphasized that dams of some sort are necessary to keep the dirt in place for vegetation to get root hold. As long as the soil can freely float off in the water it is very difficult to get living obstructions established. Brush dams are the cheapest and easiest built, they answer the purpose, and are therefore recommended. After the dams are built it is only a question of a short time before a sufficient quantity of dirt is caught to set out some of the grass or trees that have been recommended to hold the bottoms after the dams are gone. And this planting of vegetation has been the next step in the reclamation problem.

FIG. 3. Dam built for starting reclamation of gullies. The owner will set out black locust on this area. Carroll County.

Last spring some of the dams were left to catch more dirt before planting, in order that more dams could be built near them during the summer. In other cases the farmers plowed the gullies that had been dammed, together with their adjacent banks, setting them in black locust at the rate of 1200 per acre, or 6 feet apart. One area in Weakley County contains 2500 seedlings. Another in Carroll County contains 2250. In the spring of 1915 5000 black locust seedlings, nursery grown, were bought and set out by West Tennessee farmers who had been conferred with; and more than 50000 were put out in the spring of 1916. In Middle Tennessee three Lincoln County

Digitized by Google

men and one Williamson County farmer are working with the Forestry division, carrying on reclamation experiments.

In addition to this planting, 11 pounds of black locust seed were sowed by 18 men last spring (6 in Middle Tennessee and 12 in West Tennessee) who wished to grow their own seedlings for the 1917 spring setting. Some secured excellent results. G. W. Cleaver of Hollow Rock sowed ½ pound in April, in rows similar to sowing onion seed, and his young locusts are now estimated at between 3 and 5 thousand, many of which are over 5 feet high. He will use them next spring in planting a part of the area shown in Fig. 3. Joseph Johnson of Martin sowed ¼ pound and has seedlings over 6 feet high. While

FIG. 4. Dam built in August, 1915, to be planted with permanent growth in spring of 1917. Henry County.

smaller seedlings are more desirable for setting out, the size of those just mentioned shows what can be done in one season by growing young locusts from the seed, as nursery stock to be transplanted where needed to grow for posts.

Besides these projects personally conducted by the writer, many men have aided in reclamation work with active effort. Some have built dams, others have set out black locust sprouts, seedlings, bermuda grass, honeysuckle, and walnuts. The yellow poplar (*Liriodendron tulipifera*), sweetgum, and syca-

Digitized by Google

more have not yet been employed, but they are known to be useful and are recommended.

Two new growths: namely, the Kudzu vine and Himalaya vine, were taken up experimentally last spring. From what information this office has secured about the Kudzu vine it is hoped that good results may be obtained from it. It is a legume with a very deep root system which builds up its own soil to fertility. Its very heavy growth of vines is said to produce a most abundant and valuable hay for stock. The vines when running along the ground take root at the knuckles like the sweet potato vine, and from these knuckle-roots new runners grow out in the spring. Thirty land owners are experimenting with a few roots sent them and in a year or two some definite information can be secured concerning their value in reclaiming waste lands. The Himalaya vine grows similarly to the raspberry, but is much more luxuriant, bearing fruit and catching root as the tips of its branches bend down and reach the ground. These vines are used experimentally. The object is to try them out to prove their worth. The farmer should know all the forms of vegetation that can be used in restoring gullied land, and should have the information necessary to the best methods of applying them. To get some abundant, profitable growth upon these waste lands and to get it now is of paramount importance. The question of their future use can be worked out after they are restored.

Fortunately, everywhere the owners are waking up to the urgent need of tackling this problem. One farmer who has already started restoring his gullied land as suggested, said during the summer of 1915: "You may not get many men to take hold of the work right at once, but the spirit of it has now gotten into the air." And so it has proved. This general spirit of progress is all about, and while it is to be expected that not all men whose land needs more or less reclaiming have begun the actual work, yet they agree upon its importance and necessity. Despite the fact that the work has been inaugurated only a short time, many men are now conducting some form of reclamation.

Just as every farmer devotes a certain portion of time during the year to preparing his land, planting, making and har-

Digitized by Google

vesting his crop, and just as he does this systematically with a definite end in view, so he should develop some plan by which he can work at the reclamation of his waste and gullied land at a definite period each year.

With the view of calling the general attention of the public to the necessity of reclaiming waste lands, posters are now being put up along public roads and at public places, with short and plain statements, to call the attention of landowners to gully conditions which they can both remedy now and avoid in the future.

Digitized by Google

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Digitized by Google

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Maps—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 10 cents.
Map of Rutherford County, 1916; postage, 2 cents.

Digitized by Google

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvenation of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

Digitized by Google

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Digitized by Google

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

No. 2—State Supervision of Forestry, by L .C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue,
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A. Tripoli Deposit near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

Digitized by Google

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

Vol. V. No. 1—The Hydro-Electric System of Tennessee, by J. A. Switzer.
West Tennessee Gullied Lands and Their Reclamation, by R. S. Maddox.
The White Phosphates of Tennessee, by J. S. Hook.

No. 2—Physiographic Influences in the Development of Tennessee, by L. C. Glenn.
Care and Protection of Forests, by R. S. Maddox.
Two Natural Bridges of the Cumberland Mountains, by Wilbur A. Nelson.

No. 3—The Iron Ore Deposits of Lewis County, Tennessee, by Reese F. Rogers.

No. 4—The Soils of Tennessee, by C. A. Mooers.
Recent Oil Development near Oneida, Scott County, Tennessee, by L. C. Glenn.

Vol. VI. No. 1—Oil and Gas Conditions in the Central Basin of Tennessee, by A. H. Purdue.
Oil and Gas Conditions in the Reelfoot Lake District of Tennessee, by A. H. Purdue.
An Interesting Case of Spontaneous Combustion, by Paul C. Bowers.
Sketch of the Work Done by the State Geological Survey in 1915.

No. 2—Phosphates and Dolomites of Johnson County, by Olaf P. Jenkins.
Structure of the Southern Part of Cumberland County, Tennessee, in Relation to the Possible Occurrence of Oil and Gas, by Charles Butts.
Notes on Manganese in East Tennessee, by A. H. Purdue.

No. 3—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson.

The supply of Vol. 1 No. 2, Vol. III No. 1, and Vol V Nos. 1 and 2 is exhausted.

Digitized by Google

TN
24
.T2
A4

INDEX TO VOL. V

Page

Adrian, Michigan 116
Aetna 99, 106, 111
Aetna furnace 108, 109, 110, 111
Aetna mine 99
Agricultural Experiment Station 159, 162, 163, 172
Agricultural pursuits of Cumberland Plateau 52
Alabama 47, 49, 51, 95, 162
Allen's Creek 96, 99, 140, 142, 143, 144
Allen's Creek mine 140, 142, 143
Alluvial soils 155, 161
Almy or Bear Creek coal 181
Analyses, Lewis County iron ore 108-146
Anderson No. 1 well 181
Appalachian Mountain Region 44-47
Appalachian Mountains 44, 64
Appalachian structure 47
Bain, Henry F., referred to 174
Baker's prospect 108
Barker tract 139
"Barrens" type, the 167-168
Bassler 25
Beach prospect, the 116
Bear Creek 185
Bear Creek mines 183
Bear Creek, phosphate deposits along 33
Bear Creek well 183
Beardstown 33
Beatty well 183
Beech River 26, 29, 31
Beech River Phosphate Company, referred to 33
Beech River, phosphate deposits along 33
Bench lands, overflow of 161-162, 165, 168
Benton County 9, 95
Bermuda grass, value in reclamation 20-21
Bessemer ore 97
Big and Little Swan Creeks, iron ore in the vicinity of 111
Big Pigeon 46
Big South Fork of Cumberland River 183, 184
Big South Fork River 185, 186
Big Swan Creek 115
Birds and game, fire damage to 71
Black locust, value in reclamation work of the 16-18
Black walnut, use in reclaiming waste land 19
Blue phosphate rock 92, 93
Bon Air Coal & Iron Company 96, 99, 111, 142, 143
Bone phosphate of lime 93
Bottom and bench lands 171, 172
Bowers, Dr. Paul C 108, 174, 192
Bowlder or chunk ore 102
"Breccia" phosphate 23, 29
Bridge, Gooch Creek, natural 78-80

Digitized by Google

Page
Bridge, Sewanee natural 77, 78
Bristol 46, 139
Bryant, L. E., referred to 182
Bryant well, Winfield, Tennessee, record of 182
Brown, C. M., referred to 144
Brown, C. R., referred to 128
Brown hematite 100
Brown ore deposits 97
Brown prospect 144
Brown rocks (phosphate) 93
Brush Creek 144
Brush Creek Bank Nos. 1, 2 and 3 145-146
Buck's Branch, openings for phosphate along 33
Buffalo Iron Company 111, 143
Buffalo River 33, 92, 94, 117, 122, 127, 143, 144
Buffalo trails 45
Building stone 92
Burchard, E. F., referred to 104
Bureau of Soils, U. S. Department of Agriculture 173
Cadahy Bros., of Chicago 183
Cade Branch 114
Camden chert 25, 26, 33
Cane Creek 92, 130, 131
Cane Creek District 129
Caney Creek 4
Carboniferous rocks 26, 27, 31
Care and Protection of Forests 65-73
Carpenters Station 96, 119
Carroll County 9
Carroll, W. A., referred to 106
Carter's land 139
Centerville 113, 114, 136, 137, 139
Central Basin 44, 54, 56, 57, 59, 156, 163, 164, 165, 167
Central Plain 56-60
Chalybeate Springs 103
Charcoal 94, 96, 119, 143
Charles Mining Company, referred to 113
Charleston, South Carolina, Mining & Manufacturing Company 115
Charlotte Lumber Company 132-134
Chattanooga 5, 52, 59, 64
Chattanooga & Tennessee River Power Company 4
Chattanooga black shale 115, 188
Chattanooga formation 26
Cheatham estate, the L. P 130, 131, 132
Chert 97, 98, 101, 102, 103, 108, 109, 110, 113, 114
115, 116, 117, 120, 122, 125, 126, 127, 129, 131, 133, 134, 137, 142, 159
Cherty limestones 98, 117, 120, 124, 127, 140, 142
Chester County 9
Chestnut 94
Chestnut oak 94
Chicakamauga limestone 155, 161
Chickamauga limestone soil 160
Chief Creek 92, 94, 96, 117, 120, 121, 144
Christian bank Nos. 1, 2 and 3 127-129
Christian bank No. 4 143
Christian Floyd and adjoining property 128
Christian, H. T., referred to 127, 128, 143

Digitized by Google

Page
Cincinnati-Nashville uplift, axis of..... 189
Cincinnati Southern Railway..... 50
Civil War..... 49, 52, 55, 59, 61, 119
Civilization on the Central plain, development of..... 59
Clarke..... 91
Clarksville..... 54, 143
Clay..... 92, 98, 99
100, 101, 102, 106, 107, 108, 109, 110, 112, 114, 115, 117, 120, 121, 122
124, 125, 126, 127, 128, 129, 130, 134, 135, 136, 138, 140, 142, 145, 146
Clay loam..... 157
Clay soil of West Tennessee gullied land area..... 9, 11
Clay soils..... 156
Cleveland..... 5, 6
Clifton, Decatur limestone near..... 26
Clinch..... 48
Clinton..... 47, 188
C., N. O. & T. P. Railroad..... 174
Coal of Great Valley of East Tennessee..... 49
Coble property..... 109
Coble property, a prospect north of..... 110, 111
Coke..... 94, 96, 119, 143
Cole, Colonel E. R., referred to..... 119
Columbia..... 57, 96, 113, 115, 116, 126
Communication across Cumberland plateau, means of..... 51
Confederate Army..... 49, 59
Conglomerate..... 99, 101, 103, 110, 122, 140
Conglomerate and breccia ore..... 111
Consolidated Phosphate Company..... 115
Cotton Branch..... 129
Crab Orchard..... 50, 51, 52, 162
"Crawfishy" soils of Middle and East Tennessee..... 169
Crops of Cumberland Plateau region..... 52
Crossville..... 50, 51, 52
Cub Creek, occurrence of white phosphate along..... 33
Cumberland County..... 162
Cumberland Gap..... 51
Cumberland Mountains..... 50, 76, 77
Cumberland Plateau..... 49-53, 63, 64, 156, 157, 162, 163, 174, 189
Cumberland Plateau, soils of..... 162-163
Cumberland River..... 51, 56
Cumberland River, valley of..... 59
Cumberland Tableland..... 95
Davidson, Hicks & Greene Company tract (Smith tract)..... 144
Dayton Coal & Iron Company, coke ovens of..... 78
Dayton, natural bridge near..... 76
Decatur County..... 29, 95
Decatur County, phosphate deposits in..... 23, 25, 33
Decatur limestone..... 33
Decaturville..... 25, 26, 33
Devonian..... 26, 27, 31
Devonian age..... 188
Dickson..... 54
Dickson County..... 95
Distribution of white phosphates in Tennessee..... 32-33
Doe River..... 46
Dossett..... 48

Digitized by Google

Page
Dolomitic soils 159-160
Drake, N. F., referred to 97
Duck River 56, 92
Dubowich Bank 121-122
Dyestone-Region 95
Eakin, John Hill, referred to 119
Eastern Iron Region 95
Easter Oil & Gas Company's well No. 1, record of 181
Easter Well 186
East Tennessee 45, 49, 51, 63, 156, 157, 165
East Tennessee, high-grade limestone soils of 166
East Tennessee settlers, secession of the 46
East Tennessee, the dolomite ridges of 159
East Tennessee Valley 160
Eckel, E. C., referred to 29
"Economic Geology of the Waynesboro Quadrangle," referred to 97
Electric currents, direct and alternating 5
Electric generators 6
Elk River 56
Elk Valley 188
Erosion 9, 53, 54, 55, 56, 57, 73, 78, 98, 100, 103, 108, 121, 142, 160, 163, 169
Evansville line 59
Fain Bank 131
Fayette County 9
Fentress County 50, 51, 188
Fertility of soil in gullies 21
Fire damage to birds and game 71
Fire damage to fish 73
Fire damage to grazing 72
Fire damage to run-off 70, 71
Fire damage to trees 68
"Flatwoods" country 130
Flood-plain of the Mississippi 44, 62
Floyd, Henry M., referred to 128
Foerste, Dr., referred to 25
Forest fires 67, 68, 69, 70, 71, 72, 73
Forest Oil Company 183, 184
Forest reserves 157
Forests, care and protection of 65-73
Fort Payne chert 33
Franklin County 167
Franklin, formation of the independent State of 46
Franklin County, natural bridge in 76
"Freestone" formations 166
French Broad River 45, 46
Fulton 61
Gas, Oneida, Scott County 191
Geismer, H. S., referred to 106
Generators 6
Geological map of the State 155
Geology, influence of 54
"Geology of Perry County and Vicinity," referred to 97
Geology of region near Oneida, Scott County 185
Georgia 44, 49, 64, 95
Georgia Power Company 6

Digitized by Google

Page
Glenn, Dr. L. C. ... 80, 174
Goethite ... 100, 101, 142
Goodmans Prong Prospect Nos. 1 and 2 ... 130
Gordonsburg ... 113, 114, 115
Gordonsburg mining district ... 92
Gooch Creek natural bridge ... 78-80
Graham Creek, phosphate deposits along ... 33
Gravel ... 93, 98, 99, 103, 108, 109, 110, 111, 114
115, 117, 122, 126, 127, 128, 129, 131, 133, 134, 135, 138, 140, 142, 145
Grazing, fire damage to ... 72
Great Valley ... 47, 48, 64, 157, 159
Great Valley of East Tennessee ... 44, 64, 156-162
Greeneville ... 48
Grigsby, Dr. A. H., referred to ... 113, 114
Grinder and Odom banks ... 136
Grinders Bank ... 138-139
Grinders Branch ... 115
Grinders Creek ... 92, 123, 125, 126, 127, 138
Grinders Creek deposits ... 123
Gulf Coastal Plain ... 60
Gulf Embayment Plain ... 44
Gullied lands, injury to public roads ... 14
Gullied lands in West Tennessee, acreage of ... 13
Gullied lands in West Tennessee, character of ... 9-10
Gullied lands in West Tennessee, drainage of ... 10
Gullied lands in West Tennessee, economic value when reclaimed ... 13
Gullied lands in West Tennessee, history of ... 10-12
Gullied lands in West Tennessee, location of ... 9
Gullied lands in West Tennessee, moral influence on community ... 14
Gullied lands in West Tennessee, need of reclamation of ... 16
Gullied lands in West Tennessee, precipitation on ... 10
Gullied lands in West Tennessee, remaining timber on ... 15
Gullied lands in West Tennessee, temperature of ... 10
Gullied lands in West Tennessee, the need of timbered areas on ... 15
Gullied lands in West Tennessee, vegetation on ... 12
Gullies ... 67
Hale Bank ... 122
Hale's Bar ... 4, 5
Hale, John W., referred to ... 122
Hambrick, J. P., referred to ... 174
Hardin County ... 54, 61, 95
Hardin sandstone ... 26
Hardeman County ... 9
"Hard rock" deposits of Florida ... 31
Harpeth River ... 56
Hartley Branch ... 115
Hartley Branch prospect, the ... 115
Hayes and Ulrich, referred to ... 97
Hayes, Dr. C. W., referred to ... 23
Helenwood ... 185
Hematite ... 101
Henderson County ... 9
Hendren No. 1 oil well, record of ... 178-179
Henry County ... 9
Henson, West ... 130
Hickman County ... 95, 99, 111

Digitized by Google

Page
Highland Plain 53-56, 57, 59
Highland Rim, area, elevation, rainfall and soils of the..... 165-168
Highland Rim, iron ore-bearing area of the..... 91
Highways, across the boundary ridges of East Tennessee..... 45
"Hillside" furnace 96, 119
Hiwassee River 46
Hohenwald 25, 96, 106
108, 115, 123, 125, 126, 127, 128, 129, 130, 131, 132, 137, 138, 139, 143
Holston 48
Holston marble 155
Honey-comb ore 102, 110, 113
Honeysuckle, wild, in reclamation of waste land 20
Horse power 4, 5
Houston County 95
Hudson River or Cincinnatian group 188
Hughes Bank 126
Humphreys County 92, 95, 167, 168
Hydetown Oil & Gas Company..... 182
Hydro-electric system, operation in Tennessee of the..... 4-7
Hydrous iron oxide 99
Indian Creek 92, 106, 108, 109, 116
Indian Creek deposits 106
Indian Grave Gap 46
Indians 51, 58
Indian trails 45
Iron industry, history of 95-97
Iron ore deposits of Lewis County, Tennessee..... 91-146
Iron sulphides or pseudomorphs 103
Jacks Branch 134, 135
Jacks Branch-Rockhouse Creek group 134, 139
Jackson 169
Japan clover, in reclamation of waste land 20, 161
Jenkins Branch deposits 111
Jenkins Hollow 111
Jonesboro 48
Kentucky 49, 95, 162
Killebrew 95, 96
Kimmins 106, 108, 109
King, Andrew, referred to..... 130
Kingsport 48
Kingston 48
Knoxville 5, 46, 47, 48, 64
LaGrange soils, the 169
Lake Superior 97
Lamellar variety of phosphate 27-29
Land as a natural resource 8
Land holdings in oil region near Oneida, Scott County..... 194
Land office 63
Landslides 98
Langford and Long Bank 108
Langford, J. R. 108
Lawrence County 92, 95, 119, 121
Leaf litter, burning of 70
Lee formation 176, 177, 178, 179, 181, 182, 183, 184, 185
Leipers formation 115

Digitized by Google

Page
Levee system 62
Lewis County..91, 92, 94, 95, 96, 97, 102, 111, 117, 119, 121, 138, 140, 142
Lewis and Clarke overland expedition..... 91
Lewis County, Tennessee, iron ore deposits of..... 91-146
Lewis County, the soils of..... 93
Lewis, Major E. C., referred to..... 119
Lewis, Merriwether 91
Lewis Monument 116
Lick Creek, white phosphate rock near 33
Lime 94, 157, 159, 160, 162, 163, 167
Limestone, decomposition of 166
Limestone for flux, lime and fertilizer..... 92
Limestones 56, 57, 97, 98, 103
Limestone soils 55, 160, 166
Limestone valleys 49
Limestones, high grade 157
Limestones, association of phosphate with..... 27-30
Limestones, Upper Silurian 31
Limonite 98, 99,
100, 101, 102, 104, 108, 110, 113, 115, 116, 120, 122, 124, 125, 126, 127,
129, 130, 131, 132, 133, 135, 136, 187, 138, 139, 140, 141, 142, 143, 144
Linden formation 26
Linden road 130
Lindsey, Wm. H., referred to 119
Literature on Tennessee soils, references to..... 172
Little and Big Brush Creeks 144
Little Buffalo Creek 94
Little Swan Creek 115, 116
Little Tennessee 46
Livingston 55
Loams 156, 157, 159, 160, 163, 164, 168
Loess soil, the 169
Log washer 142, 143
Long, Charles, referred to 108
Lost Cove 77
Lost Creek, phosphate deposits along 33
Louisville and Nashville Railroad 48, 59
Loveless and Overbey tract 123
Lower Carboniferous 97
Low Gap Branch Prospect Nos. 1 and 2..... 113-114
Lynchburg 46
Lyon, M. F., referred to 116
Lyon tract, the 116
McClanahan & Stone 119, 142, 143
McLean 135, 136, 137, 138
McMinnville 54, 55
McNairy County 9, 61
Maddox, R. S., literature on Tennessee soils by..... 172
Madison County 9
Manganese 101, 102
Map, use of in hydro-electric system..... 7
Marble and other high grade limestone soils..... 157-159
Marion County 4
Maynard 29, 31
Memphis 61, 64, 121
Mid-Brush Creek deposits 144-145

Digitized by Google

Page
Middle Tennessee 49, 51, 53, 63, 64, 91, 156
Military road 51
Mineral resources of Great Valley of East Tennessee..... 49
Miscellaneous soils of the eastern section of West Tennessee... 170-171
Mississippian, the 186, 188
Mississippi flood-plain 44, 60
Mississippi River 10, 51, 60, 61, 62, 156, 168, 169, 171
Monteagle 71
Monterey 50, 51, 52
Montgomery County 95, 167
Mooers, C. A., referred to 155
Mooers, C. A., literature on Tennessee soils by..... 172
Morgan County 184
Morgan Spring sandstone 79
Morristown 46, 160
Morrow, J. E., referred to 130
Morton's and adjacent property 127
Mountains of East Tennessee, influence upon settlers..... 46, 47
Mount Pleasant 57, 108, 115, 119
"Mulatto" soils 160
Munn, referred to 182, 183, 184
Murfreesboro 56, 164
Murphy, William, referred to 130
Napier 96, 117, 119, 120, 121, 122, 144
Napier furnace 96, 119
Napier Iron Works 96, 117, 119, 120, 145, 146
Napier mine 99, 121
Napier Mine Nos. 1 and 2..... 117-120
Napier Mining District, the 117
Nashville 5, 51, 56, 58, 59, 64, 111, 117, 120, 140, 142, 144, 145, 146
Nashville, Chattanooga & St. Louis Railway..... 51, 59, 111
Natchez Trace 91
National forest reserves 72
Natural bridges 76, 77, 78-80
Newburg 116
New Market 160
Newman limestone 186-188, 191
Nicholson's prospects 111
Nitric acid 93
Nitrogen 159, 167
Nixon and Craig Bank 139-140
Nixon Bank Nos. 1, 2, 3, 4, 5, 6, 7, and 8..... 135-138
Nodular phosphate of South Carolina 31
Nolichucky River 46
North Carolina 45, 46
Nunnelly mine 99
Obion County 171
Ochre 100
Ocoee River 4, 7
Odom and Cheatham Lands Nos. 1 and 2..... 131-132
Odom Bank 137
Ohio River 51, 95
Oil-bearing sands near Oneida, Scott County, Analyses of..... 191
Oil Developments near Oneida, Scott County, Tennessee..... 174-194
Old Mays Place (Hughes Bank)..... 126
Oneida and Western Railway shops 181

Digitized by Google

Page
Oneida Oil and Gas Company 181
Oneida, Tennessee 174, 176, 177, 178, 179, 181, 183, 184, 185, 186, 189, 190, 192
Owens well on Station Camp Creek 183
Ordovician 25, 97
Oregon Territory 91
Osgood formation 188
Overbey, J. D. & Co., referred to 126
Overbey prospect 126
Overflow and bench lands 161, 162, 165, 168
Overflow lands in West Tennessee 171
Overton County 188
Palestine 116
Parksville 4
Parsons 26
Peeler and Carroll Bank 106
Pegram 59
Pennington shale 186
Percy mine 96, 142
Perry County 24, 25, 26, 31, 33, 54, 95, 167, 168
Perry County, phosphate deposits in 23, 25, 32, 33
Perry Hollow 144
Perry mine 99
Phosphate deposits, physical relations of the white 27-30
Phosphate in Lewis County 92
Phosphate mined near Toms Creek, quality of 33
Phosphate rock deposits, origin of the white 31-32
Phosphate rock, method of determining a 93
Phosphate rock, sedimentary rocks associated with 25-27
Phosphates of Tennessee, the white 23-33
Phosphate strata (Lewis County), thickness of the 93
Phosphate, the solubility of 31
Phosphatic matter in limestones of Central Plain 57
Phosphatic soils 164-165
Phosphates, distribution of white 32-33
Phosphoric acid 159, 160, 162, 164, 169
Phosphorus content (Lewis County iron ore) 101
Physical features of Tennessee 44
Physiographic influences in the development of Tennessee 44-64
Physiographic regions of Tennessee 44
Pickett County 50, 51
Pig iron 96, 119
Pine and Cumberland Mountains 189
Pine Creek 184
Piney Hollow 143
Pinkney, Tennessee 96, 120
Pipe line near the Oneida oil region 192
Pittsburg 192
Political Divisions of the State, the three grand 62-63
Polk County 4
Poplar 94
Post oak 94
Potash 159, 160, 164, 167, 169
Pot ore 125, 127
Power generation and transmission 4
Prospect northwest of the Skelton Bank 129

Digitized by Google

Page
Protection of forests 65-73
Purdue, A. H. 98, 119, 155
Purdue, A. H. literature on Tennessee soils by..... 172
Pyrite or marcasite, the oxidation of 103
Quartz ...98, 100, 101, 102, 111, 114, 121, 124, 131, 134, 136, 137, 138, 144
Queen and Crescent Railway 185
Railway communication through Great Valley of East Tennessee... 47
Railways of Central plain, the construction of..... 58, 59
Railways of Cumberland Plateau 51
Randolph 61
Reclamation of West Tennessee gullied land area, need of..... 16
Reclamation, State's interest in 21
Red Bank Creek 33
Red oak 94
Reese, C. L., referred to 31
Ridges forming eastern boundary of the State, description of.... 44-45
Ridges of the Great Valley of East Tennessee..... 47
Ridgetop 59
Riverside 96, 99, 127, 128, 132, 133, 139, 140, 143, 144, 145, 146
Road material, rock suitable for 92
Roads of Appalachian Mountain region 46-47
Roan Creek, white phosphate near 33
Robertson County 167
Rochell and Slayton bank 143-144
Rockhouse Creek 92, 134, 139, 140
Rockhouse Creek deposits 139
Rocks associated with phosphate rock 25-27
Rockwood 51, 52
Rogers, Reese F., literature on Tennessee soils by..... 172
Rugby 184
Rugby Land Company Well Nos. 1 and 2, condensed record of.. 183-184
Rugby Road 183
Rugby Road well 188
Rugby Road and Rugby wells 186
Rush Branch 127
Rushings Creek, phosphate deposits along 33
Safford's "Geology of Tennessee," referred to..... 44
Safford, referred to 94, 95, 96, 103
Salt lick 58
Salt Springs 57
Sand..... 99, 101, 102, 103, 108, 118, 115, 122, 124, 126, 128, 129, 137
Sandstone 50, 55, 76, 77, 97, 98, 99, 101, 110
Sandstone, Morgan Spring 79
Scott County 174, 183
Sedimentary rocks associated with phosphate rock..... 25-27
Sellards, E. H., referred to 31
Sequatchie and Elk Valleys 51, 95
Sequatchie River 50
Sevier shale 161
Sewanee 71
Sewanee conglomerate 77
Sewanee natural bridge 77, 80
Shale 50, 55, 76, 93, 97, 98, 102, 142
Sharp Mine 96, 120
Shoally Fork or Jones well, record of..... 182-183
Shubert 139

Digitized by Google

Page
Silica 101, 128, 136, 138
Silurian limestones, upper 31
Silurian and Ordovician rocks 188-189
Silurian limestones, occurrence of white phosphate in..... 33
Skelton bank 129
Skelton place and vicinity, the 130-131
Smith and adjoining property 126
Smith bank Nos. 1, 2 and 3..... 109-110
Smith prospect, the 122
Smoky Mountains, the 156-157
Soils of Lewis County, classification of..... 93
Soils of Tennessee, the 155-173
Solubility of phosphate in acidulated surface waters..... 31
Southern Iron Company, referred to 111, 143
Southern Railway 46, 47
South Pittsburg 71
South Tunnel 59
Spring Creek, white phosphate rock near..... 33
State asylum 63
State Geological Survey 108, 119, 155, 192
State Mining Department 96
State Normal School 63
Station Camp Creek 183
Steam-driven generators, operation of 5
Steam locomotive 105
Steam plants 5
Steam power 95
Steam shovels 105
Steel log washer 105, 106
Stewart County 95
Stewart Gap 78
Stillwater Branch 130
St. Louis and Tullahoma formations 98
St. Louis formation..... 103, 106, 109, 114, 117, 124, 133, 134, 140, 142
St. Louis limestone 54, 98
Stockard prospect, the 115
Stock ranges 72
Stony variety of phosphate 29-30
Storage reservoir, building of 7
Stream erosion 50
Streams of the West Tennessee plain..... 60
Subsoil 100, 157, 159, 160, 161, 162, 165, 167
Summertown 96, 119
Swan Creek 26, 112, 113, 115
Swan Creek, Big and Little 92
Swan Creek section, the 111
Sweetwater Branch 132, 133
Sycamore, value in reclamation work of the..... 20
Syndicate Oil & Gas Company..... 174, 179
Technology of oil well drilling near Oneida, Scott County 194
Tellico sandstone soil 160-161
Tennessee 65, 71, 76, 92, 94, 95, 103
Tennessee Central Railway 52, 59, 162
Tennessee, iron ore in 94, 95
Tennessee, physiographic influences in the development of..... 44-64

Digitized by Google

Page
Tennessee Power Company 4, 5, 6, 7
Tennessee River 10, 32, 33, 51, 53, 54, 60, 61, 63, 95, 157, 170
Tennessee, the woodlands of 66
Tennessee upland soils, origin of 155
Terrapin Creek 29, 30, 33
Test wells 104
Tile drainage 171
Timber 65, 66, 67, 68, 69, 70, 72, 94, 96, 157, 163, 165
Timbered areas needed on gullied lands of West Tennessee 15
Timber, Lewis County 94
Timber of Highland Plain 56
Timber remaining on West Tennessee gullied land area 15
Tobacco 168
Tobacco culture 94
Tobacco soils 166
Towns Creek, development of white phosphate rock near 32-33
Toms Creek, Perry County 26
Toomey and Hendren wells 190
Toomey No. 1 well 188, 191
Toomey No. 1 well, analysis of oil from 192, 193
Toomey No. 2 well 186, 190, 191
Toomey-West Hendren group of wells 186
Trace Creek 92, 131, 132, 133
Trace Creek deposits 131
Tracy City 71
Transmission system 6
Trans-plateau railway 52
Transported soils 93
Tree growth 67
Trees 67, 69, 70
Tuck's mill, phosphate rock shipped from 33
Tullahoma 54, 59
Tullahoma formation 106, 115
Turgite 100, 101
Turkey 71
Two natural bridges of the Cumberland Mountains 76-80
Types of civilization found in Great Valley of East Tennessee 49
Unaka Mountains 46
Unaka Range 95
University farm 162
University of Tennessee 159
Uplands 171
Upland soils 155, 156, 169
Uplands (West Tennessee) 168-169
Upper Carboniferous 186
Upper Devonian 31
Upper Swan Creek 92
U. S. Bureau of Mines 174, 192
Valley of East Tennessee 95
Valleys of East Tennessee 47
Valley region 49
Vanderford, C. F., literature on Tennessee soils by 172
Van Horn, F. B. 93
Vegetation on West Tennessee gullied land area 12
Virginia 44, 47, 48, 49, 95, 96
Wade, Bruce 97

Digitized by Google

Page
Walden Ridge 50, 79, 95
Walden Ridge, Natural bridge on eastern escarpment of..... 76
Walker, A. W. 78
Wapf Bank 125
Wapf, H. 125
Warner and Napier Mines 97
Warner Iron Company 96, 140, 141, 142
Washington 46
Watauga 48
Water power and timber, Lewis County..... 94
Water power developments, location of the..... 4
Water power of Great Valley of East Tennessee..... 49
Water power, undeveloped 92
Wayne County 54, 95, 140, 142, 190, 192
Wells and pits, method of sinking..... 104
Well records, Oneida, Scott County, Tennessee..... 176-180
Western iron belt 95
Western iron ore region 95, 97, 99, 101, 142
Western Valley of Tennessee River 61-62
West No. 1 well, record of 177-178
West Tennessee 8, 9, 11, 25, 51, 62, 63, 64, 169, 170
West Tennessee Agricultural Experiment Station 169
West Tennessee gullied lands and their reclamation..... 8-22
West Tennessee Plain 60-61
West Tennessee region, the future of..... 61
West Tennessee, soil of..... 168-172
West well 186
Whitcomb, Chas. W. 174, 176, 177, 178-189
White Bluff 59
"White horse" 99
White oak 94
White phosphates of Tennessee 23-33
White rocks (phosphate) 93
White's Creek District, phosphate in..... 33
Whitfield, Hickman County, Decatur limestone observed at..... 26
Whitthorne, Hon. J. W..... 92
Wilkins, Ashby 116
Wilkins Prospect 116-117
Wilson Branch 114
Wilson Branch-Cade Branch Bank 114-115
Winfield well 186, 188
Winfield well, record of..... 182
Wisdom ore mine 96, 119-120
Woodland 67, 68, 69, 70
Woods, firing the 94
Yarbro place, white phosphate rock on..... 33
"Yellow horse" 99
Yellow poplar, use in reclamation work of..... 18

Digitized by Google

INDEX TO VOL. VI

Page

Albertite 6
Allardt 132, 133
American Fertilizer Company, Leatherwood, Maury County, blue phosphate rock deposits mined by 198, 199
Amygdaloidal basalt 66-67
Analyses of collophanite given by Dana 63
Analyses of phosphate rocks of Johnson County, Tennessee, discussion of 61-63
Analysis of dahllite given by Dana 63
Anderson County manganese deposits in 123
Angel coal 170, 180
Annona chalk 28
Appalachian Mountains 51
Archean rocks 66, 71
Area of Reelfoot Lake 19
Argyle 14
Arkansas 19, 24, 25, 26, 27, 28, 30, 34
Arrow mine 212
Atpontley 170
Battle Creek coal 169, 172
Baxter Gentry place, phosphate deposits on 72-74
Bear Creek coal 136, 137
Bear Wallow Company, referred to 147
Beaverdam Creek 63
Beaverdam Railroad 52
Bedford County, oil and gas in 15
Bellbuckle 15
Benton County 27
Berry, E. W., referred to 26
Big Brushy Company, referred to 150
Bigby formation 9
Big Mary coal 143, 147, 151
Bingen sand 27
Biology Department at Vanderbilt University, referred to 52
Black Diamond Mine 148
Black Wax coal 144
Blanche 14
Bledsoe County, coal mines of 170-171
Bledsoe County, coals of 181
Blue Gem coal 142, 144
Blue Grass Phosphate Company, referred to 208
Blue Lick water 16
Blue phosphate rock deposits of Tennessee 198-200
Bon Air District, description of coal veins of 173-178
Bon Air District, geology of 161-162
Bowers, Paul C. 37, 52
Bradley County, manganese deposits in 112-113
Brecciated phosphate rock 57
Briceville-Coal Creek region, coal mined in 147
Bristol 52
Brown place, Charley, phosphate deposits on 86-88

Digitized by Google

Page
Brown phosphate rock deposits in Tennessee 201-204
Brown, R. B., referred to 64
Brown place, R. B., phosphate deposits on..... 84-86
Brushy Mountain coal 150
Buffalo Cove coal 132, 133
Butler 56, 64
Butler place, E. E., phosphate deposits on..... 83-84
Butler, Senator E. E., referred to..... 53, 58, 60
Butler place, Sam, phosphate deposits on..... 80
Butts, Charles, referred to 107, 165
Caddo oil and gas field of Louisiana 23
Caddo oil field of northwestern Louisiana..... 36
Cambrian rocks 66, 71
Cannon County, oil and gas in..... 16
Carroll County, reclamation work in..... 220, 221
Carter County 56
Carter County, manganese deposits in..... 117-119
Carthage 16
Caruthersville, Missouri, well sunk at..... 34
Catheys formation 9
Central Basin, nature of the rocks of..... 9-10
Central Basin of Tennessee, oil and gas conditions in..... 3-16
Century plant of the Federal Chemical Company..... 215
Charleston, S. C., Mining & Manufacturing Company..... 198
Chattanooga shale 37
Chocktaw Island 21
Classification of the phosphate rocks of Johnson County, Tennessee 57-59
Clear Creek basin 140, 141
Clifty coals 174
Coal area, the northwestern 128-137
Coal Creek, manganese ore from 123
Coal Creek coal 138, 141, 144, 147
Coal field of Tennessee, northern 128-154
Coal field of Tennessee, southern 155-183
Coal field, the northeastern 137-154
Coalmont 172
Coals of Raccoon Mountain 178-179
Coals of the northwestern area 130-137
Coal analyses, referred to 127
Cocke County 56
Cocke County, manganese deposits of..... 115-116
Cold Spring Station, phosphatic material near..... 78
Collophanite 60, 61
Columbia 15
Conditions for oil and gas 4-8
Conglomerate coals 135, 136
Conservation of Phosphate Rock in Tennessee..... 193-216
Cornersville 14
Crab Orchard Station 134
Cranberry folio, referred to 70
Cress, John, referred to 53
Cretaceous formations of Tennessee 26-28
Cumberland County 128, 159
Cumberland County, coals of 175
Cumberland County, oil and gas in..... 107-110
Cumberland Mountains, geology of 159-167

Digitized by Google

Page
Cumberland Plateau, topography and drainage of the 156-159
Cutters, method of reworking 211-212
Dahllite 59, 60, 61
Damascus, Virginia 52
Davidson County, oil and gas in..... 16
Dayton, coal mining at 183
Dean coal 143
Decatur County 27
Discovery of phosphate rock in Johnson County, Tennessee..... 53-54
Dixie coal 137, 144
Dixon Springs 16
Doe Mountain 63, 68, 69
Doe Valley 63, 69, 72
Doe Valley area, phosphate deposits of..... 90-92
Doe Valley, manganese in 121
Dolomitic limestones 54, 55, 68, 69, 70
Dolomitic limestones of Johnson County..... 92-100
Dolomites of Johnson County, Tennessee, phosphates and..... 51-106
Duck River 15
Dyersburg 23
Dyersburg, well at 29
Earthquake center, the reason of 18-23
Earthquake of 1812 18-23
Elizabethton 52-56
Embayment area 24, 25, 27, 28, 31, 32, 35
Embayment area, Cretaceous deposits of..... 26
Embayment area, difficulty in locating wells in the..... 34-35
Embayment area, encroachment of the sea upon..... 26
Embayment area, structure of 30-32
Embayment area, wells of 33-34
Erwin 56
Erwin quartzite 68, 69
Etna coal 166
Eutaw sand 25, 26, 27, 28, 29
Fayetteville 14
Federal Chemical Company, referred to..... 210
Fentress County 128
Field test for phosphate rock, method of making 53
Florence 15
Forestry Division, farms being reclaimed under the direction of.. 217
Forge Mountain 63
Forked Deer River 20
Fosterville 16
Franklin County, coal mines of 171
Fritts place, A. H., phosphate deposits on..... 78-79
Fritts place, Scott, phosphate prospecting on..... 80
Froehling and Robertson 53
Frozenhead seam 150
Fuller, M. L., referred to 22
Gas wells of the Central Basin producing..... 12-13
Gem mine 141, 142
Geological formations in Johnson County..... 66-69
Geological history of Johnson County phosphates..... 71
Geology of Reelfoot Lake area 24-29
Geology of Tennessee, by Safford, referred to..... 26
Giles County, oil and gas drilling in..... 14

Digitized by Google

Page
Gilsonite 6
Glenn, L. C., referred to 3, 26, 27
Glenn, L. C., northern coal fields of Tennessee..... 127
Goodrich coal 181
Grahamite 6
Granite rocks of Johnson County..... 66
Graysville, coal mining at..... 183
Greene County 56
Grundy County 161
Grundy County, coal mines of..... 171-172
Gulf, invasion of the 25
Gulf States, lowlands of the 24
Hamburg 37
Hamblen County, manganese deposits in 116-117
Hamilton County, coals of 181
Hampton 56
Hampton shale 67
Hardin County 27, 37
Hatchie River 20
Hayes, C. W., referred to 195, 199
Henderson 29
Henderson County 27
Henderson County, reclamation work in..... 220
Hendrix place, phosphate deposits on..... 77
Henry County, reclamation work in..... 220
Herbert Domain 171
Hermitage formation 9
Hickman, well at 29
Highland Rim 9, 10, 13
Holston Mountain 63
Honaker limestone 117
Hook, J. S., referred to 197
Hoover & Mason Phosphate Company 209
Huntington 29
Igneous rocks 6
Indian mound at Reelfoot Lake 21
Indians of the Ohio and Mississippi Rivers..... 21
Iron Mountain 53, 63, 66, 67, 69, 70, 71
Iron sulphate 40
Isoline coal 133-134
Italy coal 145
Jackson well 29
Jamestown 133
Jellico coal 141, 143, 144
Jenkins place, J. S. phosphate deposits on..... 74-78
Jenkins place, Newt, phosphate deposits on..... 79
Jenkins, Olaf P., referred to..... 51
Jenkins, Olaf P., notes on manganese supplied by..... 119
Johnson place, Andrew, phosphate deposit on..... 81
Johnson County, dolomitic limestones of..... 92-100
Johnson County, manganese deposits in 119-123
Johnson County, location and transportation facilities of..... 51-52
Jordan coal 141
Kelley coal 179
Kent coal 142, 143, 145
Kentucky 24, 28, 29, 30, 34

Digitized by Google

Page
Klondike or McGuire coal 143
Knox County 10
Knox dolomite 10, 13
Kramor coal 143
LaFollette, coal mined at 141
Lafayette formation 26, 29
Lagrange formation 29, 33
Laurel Railway 52
Lebanon 16
Lebanon formation 9
Lebanon limestone 15
Lee, Victor, referred to 52
Leipers formation 9
Leland Stanford, Jr., University 52, 59
Lewisburg 14
Limestone 6, 7, 10, 12
Limestones of Johnson County 92-100
Lincoln County, drilling for oil and gas in 14
Lincoln County, reclamation work in 221
Little Brushy Coal Company, referred to 150
Log Mountain coal 142, 143
Loosa Hatchie River 33
Louisiana 9
Louisiana oil and gas field 18
Lovettsville 14
Lower and Upper Cretaceous beds, deposition of 35
Lower Cretaceous age 25, 26
Lower Dean coal 148
Lower Pioneer coal 143
Madison County, reclamation work in 220
Maddox, R. S., reclamation of waste lands 217
Manganese 111-123
Marcasite 37, 39
Marion County, coal mines of 172
Marion County, coals of 182
Marked Tree, Arkansas 34
Marketing the output of northeastern coal field of Tennessee 152
Marshall County, oil and gas in 14
Matney, deposit of manganese near 122
Maury County, oil and gas in 14-15
Maymead 64, 72
Maynard, T. Poole, referred to 195
McGinnis, M. J., referred to 34
McNairy County 27
McRody, G. O., referred to 14
Meadow Creek Mountains 56
Memphis, oil wells put down near 17
Memphis, wells at 29, 30, 33, 35
Middle Tennessee 10, 34
Mineralogy of the phosphate rocks of Johnson County 59-61
Mingo coal 143
Miser, H. D., referred to 26
Mississippi 27, 28, 29
Mississippi River 18, 20, 26, 29, 30
Missouri 19, 30
Monoclines 7

Digitized by Google

Page
Morgan County 128
Morgan Springs coal 170, 174, 181, 183
Mountain City 51, 53, 63, 65, 66, 69, 72
Mountain City, manganese near 121-122
Mt. Pleasant phosphate field 205-209
Moxie 16
Munn, M. J., referred to 13, 33
Murfreesboro 10, 13, 15
Murfreesboro formation 9
Murfreesboro limestone 10, 11
Murman, H., referred to 154
Myer, W. E., referred to 124
Nashville, Chattanooga & St. Louis Railroad 171
Nave place, W. G., phosphate deposits on 88-89
Nelson coal 180
Nelson seam, lower 182
Nelson, Wilbur A., the southern coal field of Tennessee 155
New Etna mines 182
New Madrid 22, 36
New Middleton 16
North Carolina 51, 66
Obion River 20
Ohio River 24
Oil and gas, conditions for 4-8
Oil and Gas Conditions in the Central Basin 3-16
Oil and Gas Conditions in the Reelfoot Lake District 17-36
Oil and gas development, assistance of the geologist in 3-4
Oklahoma 34
Oliver Springs coal 150
Oliver Springs region, coal mined in 148
Oölitic phosphate rock 58
Ordovician rocks 9
Orme, Tennessee 172
Ostella 14
Overton Coal & Coke Company, referred to 131
Overton County 128
Oxidation 38-39
Ozokerite 6
Paris 29
"Peavine," the 52
Pennsylvania 9, 34
Petersburg 14
Petroleum 7
Phalen, W. C., referred to 170
Phalen, W. C., conservation of phosphate rock 193
Phosphate Rock (blue), analyses of 200
Phosphate rock (brown), three grades of 206
Phosphate rock in Tennessee, the conservation of 193-216
Phosphate rock production in Florida 193
Phosphate rock production in South Carolina 193
Phosphate rock production in Tennessee 193-194
Phosphate rock production in the United States 193
Phosphates and Dolomites of Johnson County, Tennessee 51-106
Phosphatic limestone as a source of phosphate 215-216
Phosphatic matter in igneous rocks 103-104
Physiography of Johnson County 63-66

Digitized by Google

Page
Pickett County 128
Pierce formation 9-10
Pierce shale 10, 11, 12
Pine Mountain fault 140, 142
Poplar Creek coal 148
Porters Creek and Lagrange formations 26
Porters Creek clay, the 33
Porters Creek formation 28, 29
Pratt, Dr. J. H., referred to 52
Prehistoric Man in Tennessee 124
Pruden coal 143
Pulaski 14
Purdue, A. H., oil and gas conditions in the Central Basin 3
Purdue, A. H., oil and gas conditions in the Reelfoot Lake District .. 17
Purdue, A. H., manganese in East Tennessee 111
Putnam County 128
Putnam County, coals of 176
Pyrite 37-39
Queen and Crescent Railway, coal-bearing area east of the 137
Queen and Crescent Railway, coal area west of the 128
Raccoon Mountain, coals of 178-179
Ravenscroft coal 173
Reclaiming waste lands in West Tennessee 217-224
Rector mine 145
Red Ash coal 146
Reelfoot Creek 20
Reelfoot Lake area before earthquake of 1811-12 19-23
Reelfoot Lake, area of 19
Reelfoot Lake, deep wells sunk at 35
Reelfoot Lake District of Tennessee, oil and gas conditions in 17-36
Reinke, Dr. E. E., referred to 52
Rex coal 141
Rhea County, coals of 182-183
Rhores, J. W., Jr., referred to 34
Richland coal 170-181
Rich Mountain coal 142
Ridley formation 9, 25, 29
Ridley limestone 10-11
Roane Creek Valley 63, 64, 72
Roane Creek Valley area, phosphate deposits of 84, 90
Roane Creek Valley, deposits of manganese in 122
Rock Spring coal 146
Rockwood coal 134, 135, 136
Rogers, Dr. A. F., referred to 52, 59
Ruhm Phosphate Company, referred to 209
Rutherford County 10
Rutherford County, drilling for oil and gas in 15-16
Safford, J. M., referred to 26
Sale Creek mines 181
Samburg, oil well put down near 17
Samburg 21, 30
Scott County 128
Scott, J. W., referred to 33
Selma chalk 27
Selma clay 25, 27, 28, 29
Sequatchie County, coal mines of 172-173

Digitized by Google

Page
Sequatchie County, coal conditions in eastern part of..... 183
Sequatchie Valley, drainage in the northern part of..... 158
Sevier County, manganese deposits in..... 113
Sewanee coal 169, 170, 171, 174
Shady limestone 54, 56, 59, 65, 68, 69, 70
Shady Valley 52, 63
Shady Valley, manganese ores in..... 120
Shelbyville 15
Shouns, phosphate deposits east of 89-90
Silver Lake region, phosphate deposits in..... 82-83
Smith County, drilling for oil and gas in..... 16
Smithland 14
Smith, Richard, referred to 14
Snider place, Ham, phosphate deposit on..... 80
Soddy coal 180, 181, 182
Southern Coal and Coke Company's mine, referred to..... 143
Southern Railroad, coal mines operated on..... 141
South Penn Oil Company, referred to..... 16
Splint coal 143
Spontaneous combustion, an interesting case of..... 37-40
State or Brushy Mountain coal 150
Stephenson, L. W., referred to 26, 27, 28
Stewart County 10
Stone Mountain 63, 64
Stony Creek Valley, analysis of manganese ore from..... 118-119
Sulphuretted hydrogen gas 40
Sulphur dioxide 40
Swamp angel coal 144
Tampa, Florida 52
Tennessee 24, 25, 28, 30
Tennessee as a phosphate rock producer..... 193-194
Tennessee Central Railroad, the coal field south of..... 155-183
Tennessee Central Railroad, the coal field north of..... 127-154
Tennessee Coal Field South of the Tennessee Central Railroad.. 155-183
Tennessee River 26, 37
Tertiary formations 28-29
Tertiary, recessions of the sea during the..... 31
Tertiary times 26
Thickness of the West Tennessee Embayment formations..... 29-30
Tipton, M. C., referred to 117
Tiptonville 20, 22, 36
Tiptonville dome 36
Topography and physiography of Johnson County..... 63-66
Tracy City district, geology of..... 160-162
Tracy City district, description of coal veins of..... 167-170
Trenton division of the Ordovician 9
Trimble, C. H., referred to 33
Tuscaloosa 26
Unicoi County 56
Unicoi County, manganese deposits in 117
Unicoi formation and amygdaloidal basalt..... 66-67
Union City 23
Union Oil & Development Company of Baltimore, referred to..... 16
Upper and Lower Pioneer coal 145
Upper Cretaceous 25, 26, 32, 36
U. S. Geological Survey 53, 54, 56, 67, 69

Digitized by Google

Page
Valley Forge 56
Valley of East Tennessee 10
Van Buren County, coals of 176-177
Vanderbilt University 3
Vicksburg 20
Virginia 51, 63
Virginia and Southwestern Railroad 52
Wade, Bruce, referred to 26, 37
Walden Ridge, drainage on 158
Walden Ridge district, description of coal veins of..... 178-183
Walden Ridge district, geology of 165-167
Wartrace 15
Waste lands in West Tennessee, progress in reclaiming..... 217-224
Watauga formation 59
Watauga River 64
Watauga shale 54, 56, 70
Wayne County 25
Weakley County, reclamation work in..... 220, 221
Westbourne coal 142, 143
Wells Creek Basin 10
Wells of the Embayment area 33-35
Wells sunk at Memphis 33
West Tennessee Embayment formations 29-30
West Tennessee waste lands, work of reclaiming..... 217-224
West Virginia 9, 34
White County, coals of 177
White phosphate rock in Tennessee..... 195-198
Whitthorne, B. R., referred to 15
Whitwell 172
Wilder coal 131, 132, 133
Williamson County, reclamation work in..... 222
Wills place, Baxter, phosphate deposits on 81-82
Wilson County, drilling for oil and gas in..... 16
Wimber Oil Development Company, referred to..... 15
Windrock coal 150-151
Woodbury 16
Wolf River 20, 33, 133
Work done by the State Geological Survey in 1915, sketch of the.. 41-42
Yell 14
"Yellow Hill" 69
Zcheni Coal Company, excellent cannel coal mined by..... 145

Digitized by Google

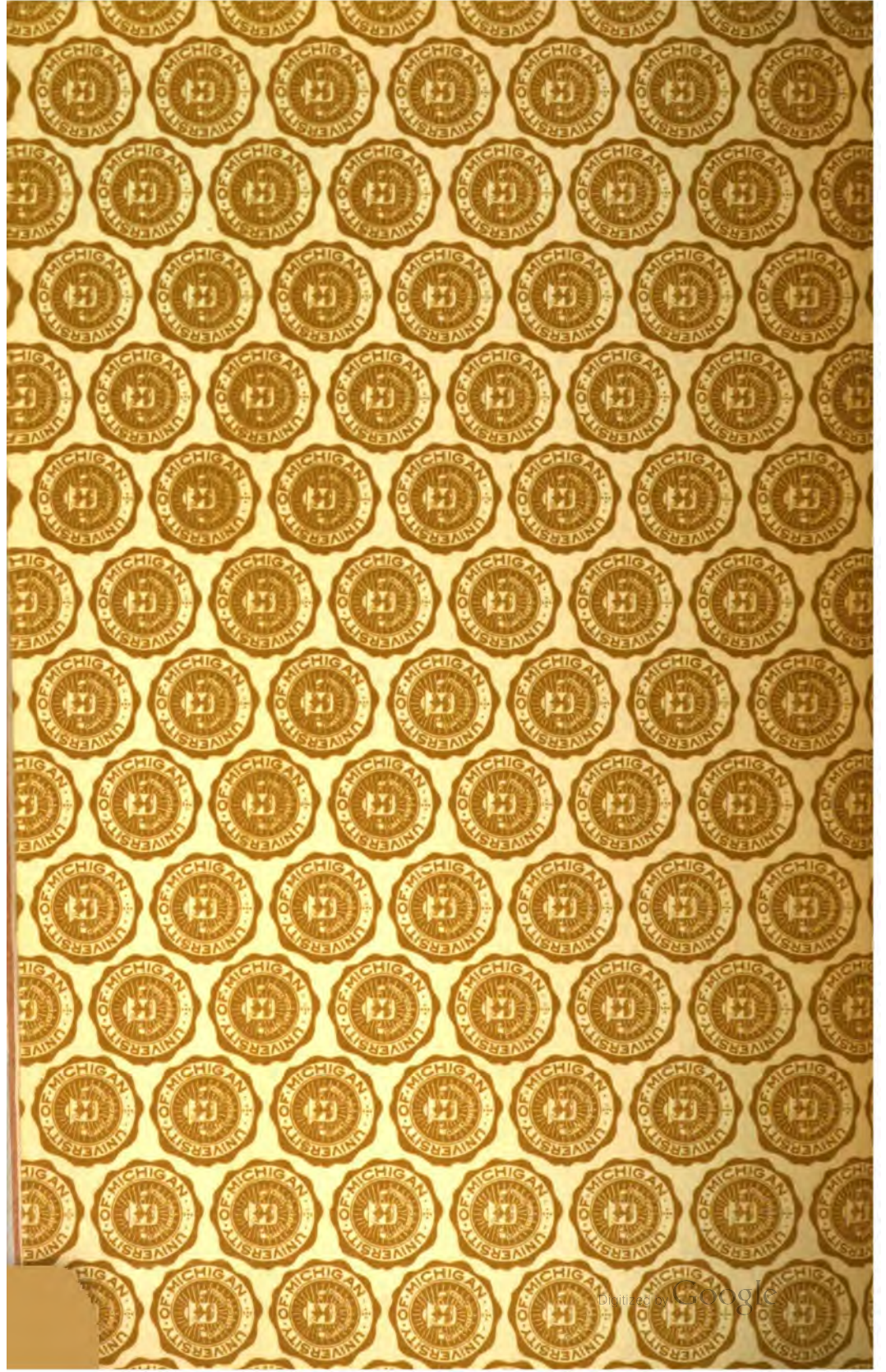
Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google


UNIVERSITY OF MICHIGAN
Digitized by Google

UNIVERSITY OF MICHIGAN
3 9015 06726 5523
FOUND
NOV 24 1926
UNIV. MICH. LIBRARY
Digitized by Google

Digitized by Google